CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Vendor selection is one of the most important decisions of purchasing function. As organizations become more dependent on vendors, the direct and the indirect consequences of poor decision-making become more severe. For example, in industrial companies where purchasing share in the total turnover typically ranges between 50-90% (Boer et al., 2001) making decisions about purchasing strategies and operations are primary determinants of profitability. In addition, several developments in technology and management further complicate purchasing decision-making. Globalization of trade and the internet enlarge a purchaser’s preferences. Changing customer preferences require a broader and faster vendor selection. Public procurement regulations demand more transparency in decision-making. New organizational forms lead to the involvement of more decision-makers. Vendor evaluation and selection is one of the most important decisions taken by the purchase manager. These developments strongly urge for a more systematic and transparent approach to vendor evaluation and selection decision making, especially regarding the area of vendor selection (Carter et al., 1998).

Operations Research offers a range of methods and techniques that support the vendor evaluation and selection decision-maker in dealing with the increased complexity and importance of his/her decisions. Examples of
such techniques are multi-criteria decision aid, problem structuring approaches, mathematical programming and data mining techniques. OR-models may enhance the effectiveness of vendor evaluation and selection decisions by:

- Aiding the purchaser in solving the right problem e.g. refraining from dropping a vendor when the delivery problems are actually caused by feeding the vendor with outdated information;

- Aiding the purchaser in taking more relevant alternatives criteria into account when making purchasing (management) decisions, e.g. more long-term considerations when deciding on make-or-buy;

- Aiding the purchaser to more precisely model the decision situation, e.g. dealing tangible factors and group decision making.

In addition, OR-models may improve the efficiency of purchasing (management) decision making by:

- Enabling automated and faster computation and analysis of decision making information, e.g. data on vendors found on the Internet;

- Enabling more efficient storage of purchasing decision making processes and access to this information in future cases, e.g. saving files that contain criteria structures for vendor evaluation;
• Eliminating redundant criteria and alternatives from the decision or evaluation process, e.g. in extensive and expensive vendor audit programs;

• Facilitating more efficient communication about and justification of the outcome of decision-making processes, e.g. when reporting to the management or the vendors.

2.2 TYPES OF VENDORS

Vendors are essential for any business. They are called as extended enterprise. Vendors can be divided into four general categories: manufacturers, distributors, independent crafts people and importation sources (Lesonsky, 2001). The first category is the manufacturers in which most retailers buy through company sales people or independent representatives who handle the wares of several different companies. Prices from these sources are usually lowest, unless the retailer’s location makes shipping freight costly.

The second category of vendors is the distributors who are known as wholesalers, brokers or jobbers. Distributors buy in bulk quantity from several manufacturers and warehouse the goods for sale to retailers. Although the prices are higher than a manufacturer’s price, they can supply retailers with small orders from a variety of manufacturers. A lower freight bill and quick delivery time from nearby distributor often compensates for the higher ‘per item cost’.

The third category is independent crafts people who are exclusive distributors of unique creations frequently offered by them and who sell through representatives or at trade shows.
The last category of vendors is importation sources in which many retailers buy foreign goods from a domestic importer who operates much like a domestic wholesaler, or depending on the company’s familiarity with overseas sources, it may want to travel abroad to buy goods.

2.3 VENDOR EVALUATION AND SELECTION PROCESS

The overall objective of the vendor evaluation process is to reduce the purchase risk and maximize overall value to the purchaser. An organization must select vendors it can do business with over an extended period of time. The degree of effort associated with the selection is related to the importance of the commodity (Robert Monczka et al 2002).

Depending on the vendor evaluation approach used, the process can be an intensive effort requiring a major commitment of resources such as time and travel budget. Formal vendor evaluation can involve a team of experts from purchasers spending several days at a vendor’s work place. The steps involved in vendor evaluation and selection process is summarized in Figure 2.1 and the details of this process are presented in Appendix 1.

2.4 VENDOR EVALUATION METHODS AND MODELS

There are many methods and models to evaluate and select vendors. The decision-making models are considered as instruments for eliciting, communicating and scrutinizing one’s personal and subjective preference structures and uncertainties. The vast majority of the decision models found apply to the vendor selection phase of the buying process. Almost two-thirds of the existing vendor selection models can be characterized as ‘single-deal' or 'package' models. These models consider the selection of a vendor for one product or a group of items at once. However, ‘multiple-deal’ models take
Recognize the need for vendor selection

Identify key sourcing requirements

Determine sourcing strategy

Identify potential supply sources

Limit vendors in pool

Determine the method of vendor evaluation and selection

Select vendor

Figure 2.1 Vendor evaluation and selection process

into account interdependencies that could exist among different products in or across the product groups. For example, a vendor may offer a larger discount based on total sales volume, irrespective of the product mix. Order costs could be minimized by combining orders for several products into one single order form. Quality audits for different products might be executed simultaneously. Multiple-deal models also take into account that a vendor may perform on different levels within a product group. For example, a vendor can produce high-quality brake shoe assembly, but deliver low-quality brake shoe spring. Some of the methods and models used for vendor evaluation and selection are explained (Boer et al., 2001) briefly in the following sections.
2.4.1 Qualitative Methods

Qualitative methods may include tools for visualizing and analyzing the decision-maker's perception of a problem situation and tools for brainstorming about possible (alternative) solutions. The collection of quantitative methods comprises a wide variety of approaches. Data-mining techniques can be used to analyze similar decisions made in the past in order to derive general patterns and decision rules that may subsequently be used to improve the efficiency and choices of future decisions. Optimization techniques, such as linear programming, may aid a decision-maker in finding optimal solutions of problems that can be described as minimizing some cost function. Multi-criteria decision analysis techniques support the decision-maker in systematically evaluating a set of alternatives on several criteria which may be of different nature (Boer et al. 2001).

2.4.2 Categorical Methods

Basically, categorical methods are qualitative models. Based on the historical data and the buyer’s experience, current or familiar vendors are evaluated on a set of criteria. The evaluations actually consist of categorizing the vendor’s performance on a criterion as either ‘positive’, ‘neutral’ or ‘negative’. After a vendor has been rated on all criteria, the buyer gives an overall rating, again through ticking one of the three options. In this way, vendors are sorted into three categories. The categorical method has been discussed widely by Zenz (1981) and Timmerman (1986).

2.4.3 Data Envelopment Analysis (DEA)

DEA is built around the concept of ‘efficiency’ of a decision alternative. The alternatives are evaluated on benefit criteria (output) and cost criteria (input). The efficiency of an alternative (e.g., a vendor) is defined as
the ratio of the weighted sum of its outputs (i.e., the performance of the vendor) to the weighted sum of its inputs (i.e., the costs of using the vendor). For each vendor, the DEA method finds the most favorable set of weights, i.e., the set of weights that maximizes the vendor's efficiency rating without making its own or any other vendor's rating greater than one. In this way the DEA method aids the buyer in classifying the vendors (or their initial bids) into two categories: the efficient vendors and the inefficient vendors. Weber has primarily discussed the application of DEA in vendor selection Weber and Ellram (1992), Weber and Desai (1996) and Weber et al.,(1998). Apart from just categorizing vendors, Weber shows how DEA can be used as a tool for negotiating with inefficient vendors. Other works featuring DEA in vendor selection are Papagapiou et al (1996) and Liu et al (2000).

2.4.4 Cluster Analysis (CA)

CA is a basic method from statistics which uses classification algorithm to group a number of items which are described by a set of numerical attribute scores into a number of clusters such that the differences between items within a cluster are minimal and the differences between items from different clusters are maximal. Obviously, CA can also be applied to a group of vendors that are described by scores on some criteria. The result is the classification of vendors in clusters of comparable vendors (Hinkle et al 1969) and (Holt 1998)

2.4.5 Case Based Reasoning (CBR) Systems

CBR systems fall in the category of the so-called Artificial Intelligence (AI) approach. Basically, a CBR-system is a software-driven database which provides a decision-maker with useful information and
experience from similar, previous decision situations. CBR is still very new and only a few systems have been developed for purchasing decision-making. Ng et al (1995) developed a CBR system for the pre-qualification of vendors.

2.4.6 Linear Weighting Models

In linear weighting models, weights are given to the criteria, the biggest weight indicating the highest importance. Ratings on the criteria are multiplied by their weights and summed up in order to obtain a single figure for each vendor. The vendor with the highest overall rating can then be selected (Zenz 1981 and Timmerman 1986). Over the past 20 years, a wide variety of slightly different linear weighting models have been suggested for vendor selection.

There are three adaptations of linear weighting model in the literature. The first adaptation concerns the compensatory nature of the basic linear weighting model. In the compensatory model, a high rating on one criterion can compensate a low rating on another criterion, whereas in non-compensatory models, different minimum levels for each criterion are required. The outranking approach suggested by Boer et al (1998) can be described as quasi-compensatory. This approach, among other things, allows the buyer to specify limits in advance to the compensation for bad scores on one or more criteria. Grando and Sianesi (1996) suggest their rating model to be non-compensatory since they do not combine ratings on different criteria into one overall rating, but only provide separate information to the decision maker. However, this does not seem to give enough guidance in the practical case implementation of their model, where they still suggest applying weights to the different criteria. Gregory (1986), who introduces two methods for splitting orders among vendors that receive the same maximum rating, constitutes the second adaptation.
Thirdly, a large number of adaptations have been suggested in order to make linear weighting models better capable of dealing with the uncertainty and imprecision associated with vendor selection. Soukup (1987) proposes a simulation-based approach to account for uncertainty with respect to the demand for the item or service purchased. Some adapted models specifically account for the imprecision of the rating mechanism itself. Nydick and Hill (1992), Barbarosoglu and Yazgac (1997), Narasimhan (1983) and Masella and Rangone (2000) propose the use of the Analytic Hierarchy Process (AHP) to deal with imprecision in vendor selection. In short, AHP circumvents the difficulty of having to provide point estimates for criteria weights as well as performance scores in the basic linear weighting model. Instead, using AHP, the buyer is only required to give verbal, qualitative statements regarding the relative importance of one criterion versus another criterion and similarly regarding the relative preference for one vendor versus another on a criterion. Sarkis and Talluri (2002) propose the use of the Analytical Network Process (ANP), a more sophisticated version of AHP, for vendor selection. Willis et al. (1993) also use such pair wise comparisons among vendors, measuring each criterion in terms of its specific unit of analysis.

Another group of authors has suggested various statistical techniques to deal with imprecision when using linear weighting models. Williams (1984) proposes the use of conjoint-analysis in deriving criteria weights. Min (1994) and Petroni and Braglia (2000), respectively, apply the so-called ‘indifference trade-off’ method and principal component analysis for essentially the same purpose. Although the techniques differ, they have one thing in common that the buyer does not directly have to provide precise numerical criteria weights. Thompson (1991) proposed Monte Carlo simulation and Thurston case V scaling technique, respectively. Again, the buyer does not directly have to set criteria weights and assign performance
scores on the criteria. Instead, it suffices to give ranges of scores or simply qualitative rank-order information.

2.4.7 Fuzzy Set Theory (FST)

A number of investigators suggest use of FST to model uncertainty and imprecision in vendor selection situations. In short, FST offers a mathematically precise way of modeling vague preferences for example, when it comes to setting weights of performance scores on criteria. Simply stated, FST makes it possible to mathematically describe a statement like: ‘criterion X should have a weight of around 0.8’. FST can be combined with other techniques to improve the quality of the final tools. An example is presented by (Morlacchi et al 1997), who has developed a model that combines the use of fuzzy set with AHP and has implemented it to evaluate small vendors in the engineering and machine sectors. In a subsequent development of his work, (Morlacchi 1999) focuses on the design process of such vendor evaluation model, pointing to the advantages and the disadvantages of using hybrid approaches of techniques. In addition, Li et al (1997) and Holt (1998) discuss the application of FST in vendor selection.

2.4.8 Total Cost of Ownership (TCO) Models

TCO-based models attempt to include all quantifiable costs in the vendor selection that are incurred throughout the purchased item's life cycle. Following Ellram et al (1994), a distinction can be made between (a) pre-transaction, (b) transaction and (c) post-transaction costs. TCO-based models for vendor selection basically consists of summarization and quantification of all or several costs associated with the selection of vendors and subsequently adjusting or penalizing the unit price quoted by the vendor with this figure in some way. For large organizations with computerized cost
accounting systems, Timmerman (1986) has proposed the so-called cost-ratio method. This method collects all costs related to quality, delivery and service, and expresses them as a benefit or penalty percentage on unit price. Monczka and Trecha (1988) and Smytka and Clemens (1993) combine a total cost approach with rating systems for criteria such as service and delivery performance for which it is more difficult to obtain the cost figures. All these total cost approaches are single-deal models and are applicable to relatively simple cases where data cost can be gathered using a spreadsheet.

### 2.4.9 Mathematical Programming Models

Given an appropriate decision setting, Mathematical Programming (MP) allows the decision-maker to formulate the decision problem in terms of a mathematical objective function that subsequently needs to be maximized (e.g., maximize profit) or minimized (e.g., minimize costs) by varying the values of the variables in the objective function (e.g., the amount ordered with vendor X). On the one hand, it may be argued that MP-models are more objective than rating models because they force the decision-maker to explicitly state the objective function. On the other hand, MP-models often only consider the more quantitative criteria.

Apart from Chaudhry et al (1993), Weber et al (1993), Pan (1989), Das and Tyagi (1994) and Buffa and Jackson (1983), all mathematical programming models consider several products simultaneously. Many of the mathematical programming models (Pan, 1989; Chaudhry et al., 1993; Rosenthal et al., 1995; Sadrian and Yoon, 1994) assume predetermined levels on quality, service and delivery constraints. Weber and Current overcome this problem by using more complex weighting and constraint methods and presenting trade-off curves among the multiple objectives as decision support to purchasing managers. Weber and Desai (1996) propose
Data Envelopment Analysis (DEA) for the evaluation of vendors that have already been selected. Weber et al., (1998) combine MP and the DEA method to provide buyers with a tool for negotiations with the vendors that were not selected right away as well as to evaluate different numbers of vendors to use (Weber et al., 2000). Karpak et al., (1999) use goal programming to minimize costs and maximize quality and delivery reliability when selecting vendors and allocating orders between them.

Some of the mathematical programming models (Chaudhry et al 1993; Rosenthal et al 1995; Sadrian and Yoon 1994; Ganeshan et al 1999) focus on the modeling of specific discounting environments. Akinc (1993) concentrates on decision support regarding the number of vendors. Benton (1991) presents a heuristic procedure to solve the multiple item problems with a non-linear objective function. Current and Weber use facility location model constructs for the vendor selection problem. Das and Tyagi (1994) develop a decision support system for a wholesaler where the selection of the manufacturer is only one of the several factors that have to be optimized in order to minimize the total cost of the wholesaling service. Other issues include selecting warehouses, assigning transportation modes and determining the service level to retailers. Only Bender et al (1985), Buffa and Jackson (1983) and Degraeve and Roodhooft (2000) simultaneously consider the inventory management and vendor selection decisions. However, according to Bender et al (1985), the mathematical programming model formulation is not included while Buffa and Jackson (1983) only solve a single-item problem. Degraeve and Roodhooft, (1998) developed a mathematical programming model that minimizes the total cost of ownership of the vendor selection and inventory management policy using activity-based costing information. Degraeve and Roodhooft, (2000) extend this methodology to the service sector in developing an airline selection model for the procurement of business travel. Finally, Ghousypour and O’Brien (1998) combine AHP and
MP in order to take into account tangible as well as intangible criteria and to optimize order allocation among vendors.

2.4.10 Statistical Models

Statistical models deal with the stochastic uncertainty related to the vendor selection. Although stochastic uncertainty is present in most types of purchasing situations, e.g., by not knowing exactly how the internal demand for the items or services purchased will develop, only very few vendor selection models really handle this problem. The published statistical models only accommodate for uncertainty with regard to one criterion at a time. Ronen and Trietsch (1988) develop a decision support system for vendor selection and ordering policy in the context of a large one/off project where the order lead time is uncertain. Soukoup (1987) introduces a simulation solution for unstable demand in his rating model.

2.4.11 Artificial Intelligence (AI) based Models

AI-based models are based on computer-aided systems that, in one way or another, can be ‘trained’ by a purchasing expert or historic data. Subsequently, non-experts who face similar but new decision situations, can consult the system. Examples of methods based on artificial intelligence (AI) technology that have been applied to vendor selection include neural networks and expert systems. Although only few examples of AI methods applied to the vendor evaluation problem can be found in the literature to date, it is important to investigate these methods for their potentialities. Because of newness of some methods, such as Internet-based technology, only few examples with demonstrative character are already available.
One of the strengths of methods such as Neural Networks is that they do not require formalization of the decision-making process. In that respect, Neural Networks can cope better with complexity and uncertainty than traditional methods, because AI-based approach are designed to be more akin to human judgment functioning.

The user of the system only has to provide the Neural Network with the characteristics of the current situation, e.g., the performance of the vendor on the criteria. The Neural Network subsequently makes the actual trade-off for the user, based on what it has learned from the expert or cases in the past. At the same time, this strength can be seen as a weakness because it also implies that the user of the Neural Network will not be able to explain the trade-off to others, for example, to vendors that will not receive business. This makes Neural Networks primarily suitable for situations where external justification is less important or as a shadow method in combination with a traditional method. Albino and Garavelli (1998) present a decision support system based on Neural Networks. The model is an adaptive back-propagation network for subcontractor rating for construction firms. This type of network learns to rate subcontractors directly on the basis of some examples and does not require formalization of the decision-maker expertise in terms of decision-rules.

Khoo et al (1998) discuss the potential use of an internet-based technology called Intelligent Software Agents (ISA) which is generally used for automating the procurement of goods. Khoo et al (1998) suggested different types of agents such as learning agents and shopping agents that can be applied to the vendor selection problem. They developed a simple model to demonstrate the effectiveness of using ISAs for electronic sourcing.
Another AI technology, Case-Based Reasoning (CBR) systems is proposed by Cook (1997). This technology is very new and only a few CBR systems have been developed for the use in purchasing decision-making, but some characteristics of CBR systems such as the capability to use information from previous negotiations and the easy training of the system, make them interesting in connection with vendor selection. Another AI-technology used in vendor evaluation is expert systems. Vokurka et al (1996) developed an expert system able to support the vendor selection.

2.4.12 Multi Criteria Decision Making Models

Multi Criteria Decision Making (MCDM) is the most well known branch of the general class of Operations Research models which deal with decision problems under the presence of a number of decision criteria. MCDM is divided into Multi-Objective Decision Making (MODM) and Multi-Attribute Decision Making (MADM).

In the vendor selection process, the final choice is often multi-objective; that is, firm’s decisions are driven by more than one objective (criteria). Multi Criteria Decision Aid (MCDA) methods (Zeleny 1982) refer to making decisions in the face of multiple, often conflicting objectives, and aim to support the decision-maker in arriving at the best compromise solution. Specialists in multi-criteria decision aid have made a habit of dividing MCDA methods into three main families, even if the boundaries between them are rather fuzzy, namely, multiple attribute utility theory, outranking methods, and interactive methods.

PROMETHEE (Preference Ranking Organization METHod for Enrichment Evaluation) method is one of the MCDA used for aggregate evaluation. It is generally integrated with the GAIA (Geometrical Analysis
for Interactive Assistance) procedure, a visual interactive modeling technique, in order to put in evidence conflicts/convergence between criteria, strengths/weaknesses of solutions, incomparability between alternatives, essential or useless information, and especially the characteristics of the best theoretical decision. It is also possible to investigate clearly the quality of the alternatives with respect to different criteria. The possibility of using the concept of “pseudo-criterion” versus “real-criterion” is another key issue in PROMETHEE methodology. Indeed, the indifference or gradual degrees of preference have to be associated to the deviations observed between the evaluations. The possibility of introducing indifference/strict preference thresholds is important, as compensatory effects are limited and controlled; this permits the analyst to deal well with uncertainties that usually emerge in such problems. The decision-maker can set limits in advance to the compensation for bad performance on one or more criteria.

Boer et al., (1998) have found an interesting application of another outranking method (ELECTRE I) in vendor selection. ELECTRE (ELimination Et Choix Traduisant la REalite) and PROMETHEE are based upon the same principles (Roy 1978). Both methods take into account equivocality, manage qualitative criteria enabling a very flexible elicitation of preferences, manage non-compensatory decision logic and deal very well with intangible and qualitative aspects.

The only difference between these two multi-criteria aggregation procedures is that PROMETHEE introduces more functions (six) to describe decision-making preferences for each criterion with a clearer interpretation of the parameters (Threshold values have a clear meaning in terms of the alternatives). The “stability of the results”, (how small deviations in the value of threshold parameters affect final ranking) - is higher in PROMETHEE than in ELECTRE III (Brans and Mareschal 1986).
2.5 OBSERVATIONS FROM PREVIOUS RESEARCH WORK

Analysing the papers on vendor evaluation and selection, starting from the seminal work of Dickson (1966) right up to the most recent ones, it is observed that the approach for the vendor selection problem has greatly changed. The evolution of vendor evaluation and selection reveals the number and variety of criteria used. Based on the empirical data collected from 170 purchasing managers, Dickson (1966) identified quality, cost and delivery performance history as the three most important criteria in vendor selection. This evolution reveals the mathematical tools used for vendor selection and the evaluation and selection used over a period of time. Previous investigators used weighted sum algorithm predominantly. Then gradually they focused their attention on more sophisticated methods such as fuzzy logic and neural network applications (Albino et al 1998).

Weber et al., (1991) while reviewing 74 articles about vendor selection problem stated that only 10 articles applied mathematical programming to vendor evaluation and selection. They have given specific attention to criteria and analytical methods used in the vendor selection process. Furthermore, the criteria mentioned by Weber et al (1991) are highly situation specific. Also, Weber et al (1991) have defined different purchasing environments quite broadly and vaguely as ‘JIT’, ‘MRP’, general industrial purchasing or a specific sector. Again, it does not follow why one decision method would be appropriate for a JIT environment and not for a MRP environment. Situational factors such as the number of vendors available, the importance of purchase and/or the vendor relationship and the amount and nature of uncertainty present, are far more determinative for the suitability of a certain decision method in a particular purchasing situation.
Ghodsypour and O'Brien (1998) used linear programming, mixed integer programming approach, goal programming techniques and multiple objective programming for vendor selection. Nevertheless, De Boer et al (1998) observed that purchasing managers have only just begun to explore the potential of Operations Research for dealing with the vendor selection decision. They also reviewed the different models and tools offered by OR for making this decision. These range from brainstorming methods to multi-criteria optimization techniques.

Performance dimensions found in the literature for example, regard the total cost of supply (Ellram 1996), just-in-time delivery capabilities (Willis et al., 1990), co-operation in partnership agreements (Briggs 1994), environmental issues (Enarsson 1998) and supply chain aspects (Beamon 1999). Lamming et al (1996) focused on ‘relationship assessment’, that is, the assessment of the overall partnership dimensions, underlying the necessity for a joint customer-vendor evaluation approach. Various researchers have reported on the systematic approach to vendor evaluation and selection decision-making (Vonderembse and Tracey 1999; Weber, 1991; De Looff 1997).

Holt (1998) and Degraeve et al (2000) considered the final choice phase in the vendor selection process, but Boer et al (2001) recognized several decision-making steps prior to the ultimate choice phase, such as the formulation of criteria and the pre-qualification of (potential) vendors. Degraeve et al (2000) only evaluated the existing decision models for re-buy purchases. Weber et al (1991) studied vendor selection with regard to (1) the particular criteria mentioned in the article, (2) the purchasing environment, and (3) the decision technique used. This approach may not be the most effective one for helping a purchaser to find an adequate decision method in a particular situation, as a specific set of criteria may be accommodated by
more than one method. Although several authors on this subject suggested a variety of factors to be taken into account (Oxenfeldt 1979; Pinsoneault and Kraemer 1989), importance and complexity appeared to be the main underlying determinants.

A review of decision making methods reported in the literature for supporting vendor selection process is given by Boer et al (2001). Nasr Eddine Dahel (2003) presented a multi-objective mixed integer programming approach to simultaneously determine the number of vendors to employ and the order quantities to allocate to these vendors in a multiple product, multiple vendor competitive sourcing environment. Tracey and Tan (2001) employed confirmatory factor analysis and path analysis to examine empirically the relationship among vendor selection criteria, vendor involvement on design team and customer satisfaction.

Chen et al (2006) developed a vendor evaluation model considering the qualitative and quantitative criteria for vendor selection in an outsourcing manufacturing organization. They proposed an integrated model by combining the Analytical Hierarchy Process (AHP) and Grey Relational Analysis (GRA) into a single evaluation model.

Semra (2003) studied vendor selection and evaluation for a manufacturing company under lean philosophy. A five-step multi attribute selection model is used for vendor evaluation and selection. Hartley et al (1996) compared the vendor selection practices based on a survey of companies at different levels in the auto industry. They considered companies’ position in the supply chain for vendor selection. Talluri and Narasimhan (2003) proposed a max-min productivity based approach that derives vendor performance variability measures, which are then utilized as a non-parametric statistical technique in identifying vendor groups for effective
selection. Ghodsypour and Brien (1998) proposed an integration of analytical hierarchy process and linear programming to consider both tangible and intangible factors in choosing the best vendors and placing the optimum order quantities among them such that the total value of purchasing becomes maximum. This model can be applied to vendor selection with and without capacity constraints. Dulmin and Mininno (2003) investigated the contribution of multi-criteria decision making method (PROMETHEE / GAIA) to solve multi objective nature of vendor selection problems. Also, they studied simultaneous change of the weights (importance of performance criteria). Boer et al (2001) reviewed decision-making methods reported in the literature for supporting vendor selection process. Their work is an extension of previous work done by Weber et al (1991), Holt (1998) and Deglaeve et al (2000a).

According to Alberto De Toni et al (1998) the selection of the right vendor is perhaps the most important responsibility of the purchasing function. The vendor evaluation and selection system identify the vendors best equipped to meet the customer's expected level of performance, and check them periodically and systematically (Baily and Farmer 1990). Thus, the branch of studies concerning ‘vendor evaluation and selection’ is particularly rich and different conceptual models for vendor evaluation and selection have been worked out depending on the firm's situation, priorities, activities and competencies. Vokurka et al (1996) have developed an expert system that covers multiple phases in the vendor selection process. The knowledge base of this expert system has been developed based on information available in the literature and using a senior purchasing manager. Users (non-experts) can consult this system to obtain suggestions like which criteria has to be used in a particular situation.
Table 2.1 gives the list of vendor evaluation techniques used by different investigators. The next section explains why AHP is used in this research.

Table 2.1  Vendor Evaluation Techniques used by different Investigators

<table>
<thead>
<tr>
<th>Evaluation Technique</th>
<th>Investigators</th>
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<tbody>
<tr>
<td>Weighted linear models</td>
<td>Lamberson et al (1976), Timmerman (1986), Wind and Robinson (1968)</td>
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<tr>
<td>Linear programming</td>
<td>Pan (1989), Turner (1988)</td>
</tr>
<tr>
<td>Analytical network process</td>
<td>Sarkis and Talluri (2002)</td>
</tr>
<tr>
<td>Matrix method</td>
<td>Gregory (1986)</td>
</tr>
<tr>
<td>Multi objective programming</td>
<td>Weber and Ellram (1993)</td>
</tr>
<tr>
<td>Total cost of ownership</td>
<td>Ellram (1994), Monezka and Trecha (1988)</td>
</tr>
<tr>
<td>Human judgment models</td>
<td>Patton (1996)</td>
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<tr>
<td>Principal component analysis</td>
<td>Petroni and Braglia (2000)</td>
</tr>
<tr>
<td>Interpretive structural modeling</td>
<td>Mandal and Deshmukh (1994)</td>
</tr>
<tr>
<td>Game models</td>
<td>Talluri (2002)</td>
</tr>
<tr>
<td>Discrete choice analysis experiments</td>
<td>Verma and Pullman (1998)</td>
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<tr>
<td>Conjoint analysis</td>
<td>Williams (1984)</td>
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<tr>
<td>Indifference trade off method</td>
<td>Min (1994)</td>
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<tr>
<td>Principal component analysis</td>
<td>Petroni and Braglia (2000)</td>
</tr>
<tr>
<td>Multi Criteria Decision Aid (MCDA)</td>
<td>Zeleny (1982)</td>
</tr>
<tr>
<td>Rough sets theory</td>
<td>Slowinsky (1992), Pawlak and Slowinsky (1994)</td>
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<tr>
<td>Value focused thinking</td>
<td>Kenney (1994)</td>
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<tr>
<td>Grey relational analysis</td>
<td>Ching Chow Yang et. al (2006)</td>
</tr>
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Tsai et al (2003) utilized the Grey relational analysis in the Grey theory to establish a complete and accurate evaluation model for selecting vendors which reduces the purchasing cost and increase the production efficiency and overall competitiveness. Das and Shahin (2003) formulated an intelligent vendor selection model as a mixed integer program that evaluates the submitted E-Market proposals and prescribes a supply strategy.


Bayazita and Karpakb (2005) used AHP model with sensitivity analysis to choose the best supplier and place the order quantities among them for a construction company. Garfamy (2005) studied in his masters' thesis that the relationship between supplier selection and business process improvement. Kim et.al (2005) examined various product and management characteristics of small manufacturing enterprises (SME) to determine critical factors that award qualified suppliers of mass merchandising companies. Klundert et al (2005) reported a model for selecting international telecommunication carriers for a major telecommunication service provider. The authors considered volume discounts also in the model and showed that a special case of their model results in a min-cost flow model. Pi and Low (2005) have developed a system for vendor evaluation and selection based on
the four attributes (quality, on time delivery, price and service) which are transferred to the quality loss function and combined to one decision variable. Arunkumar et al (2006) used lexicographic method in vendor selection that enables the decision-maker to establish the limit for defective components and late deliveries as constraints in the model. Demand can be exactly met considering the defective components present in the supply. Manoj Kumar et al (2006) developed chance-constrained programming to solve a supplier quota allocation problem in which realistic constraints such as buyers’ demand, budget allocation to individual vendors, are also modeled. Shyur and Shih (2006) proposed five-step hybrid process for vendor evaluation, which incorporates the technique of an analytic network process (ANP) and Technique for Order Performance by Similarity to Idea Solution (TOPSIS).

Moynihan et al (2006) developed a prototype decision support system for procurement which focuses primarily on procurement operations within a manufacturing environment using Integer programming and analytical hierarchy process models are incorporated to support these objectives. Lau et al (2006) proposed a generic model for supplier selection, focusing on the methodology to benchmark the potential suppliers and to provide a comparison of performance measures based on a number of relevant criteria. In order to validate the feasibility of the proposed system, the authors used existing artificial intelligence tools that have been developed for selecting and benchmarking suppliers for manufacturing firms. Xiao et al (2006) proposed a new approach for online supplier selection, based on state of the art literature and existing industry practices.

Palaneeswaran (2006) used AHP to select right suppliers to supply construction materials. Pi and Low (2006) developed a more accurate and easier method for quantifying the supplier’s attributes using Taghuchi method and AHP.
Ernst et al (2007) presented a simple decision rule for choosing vendors based on their lead-time specifications. The authors studied the effects of lead-time in the context of standard (Q, r) inventory policy. They used the coefficient of variation of the demand per unit time in conjunction with the vendors’ specifications to produce a comparative index. Then the vendors are evaluated based on this index. Instead of selecting the vendor with the smallest mean lead-time, this approach leads to the selection of the vendor who minimizes operating costs. Noorul Haq and Kannan (2007) developed an effective and efficient hybrid normalised multi criteria decision making model for evaluating and selecting the vendor using an Analytical Hierarchy Process (AHP) and Fuzzy Analytical Hierarchy Process (FAHP) and an integrated approach of Grey Relational Analysis (GRA) in a Supply Chain Model (SCM).

Rao (2007) developed a logical procedure for solving the vendor selection problem in a supply chain environment with multiple objectives. The procedure is based on a combined Analytic Hierarchy Process (AHP) and a Genetic Algorithm (GA) method. Sucky (2007) proposed decision making approach for strategic vendor selection based on the principles of hierarchical planning which neglects the interdependencies in time arising from investment costs of selecting a new vendor and costs of switching from an existing vendor to a new one. Gencer and Gurpinar (2007) considered supplier selection problem as a multi criteria decision problem and developed a model aiming the usage of analytic network process (ANP) in supplier selection. Zhu Xue-zhen (2007) proposed a dynamic model based on AHP and BSC for long-term strategic vendor selection problems.
2.6 WHY AHP IS USED?

AHP is based on the innate human ability to make sound judgments about any problems. The decision-maker can express his preference between each pair of elements verbally. The scale used for comparisons in AHP enables the decision-maker to incorporate experience and knowledge intuitively. AHP facilitates decision making by organizing perceptions, feelings, judgments, and memories into a framework that exhibits the forces that influence a decision. In AHP, a problem is structured as a hierarchy. Once the hierarchy has been constructed, the decision-maker begins the prioritization procedure to determine the relative importance of the elements in each level and a better decision can be taken. In many existing decision models for supplier selection, only quantitative criteria are considered. However, a vendor selection problem is a multi-objective problem, encompassing many quantitative as well as qualitative factors. Since AHP is capable of dealing with these kinds of decision problems, it has been selected as a decision analysis tool. The steps involved in AHP are presented in Appendix 2.

2.7 RESEARCH PROBLEM AND METHODOLOGY

2.7.1 Need for this research

Many researchers, highlighting the multi-attribute nature of vendor selection have focused their attention on two major issues. These issues are identification of what criteria should be considered in the assessment of vendors and the application of multi-attribute decision-making techniques based on various selection criteria which evaluate the overall suitability of alternative vendors. Very few studies considered ‘customer expectation’ as one of the component for vendor evaluation and selection. Very few research works address the importance of product prioritization in vendor evaluation
and selection. The integration of product prioritization and customer expectations into the vendor evaluation and selection has not been addressed so far. Hence, a decision-making model is needed to integrate both product prioritization and customer expectation for evaluation and selection of vendors.

2.7.2 Research problem

In the evaluation and selection of vendors, product prioritization and customer expectations are to be integrated with other factors like ‘on time delivery’. For this purpose, it is also necessary to develop an appropriate Multi-Criteria Decision Making (MCDM) model (evaluative model) and integrate it with an optimization model (generative model) where well defined objectives and constraints are to be addressed. The results of this integration are expected to give rise to an optimal allocation of a set of products to a set of vendors.

2.7.3 Research objectives

i) To develop a unified methodology for the evaluation and selection of vendors, considering product ranking according to product prioritization and customer expectations.

   a) Incorporate the integration of the evaluative model (AHP) and generative model (ILP) in the above unified methodology.

   b) Optimize the assignment of vendors by developing appropriate optimization model.

ii) To apply and test the above methodology in a two-stage supply chain of a wholesale company and analyze the results.
2.7.4 Research methodology

The tools and methods used to solve the above defined problem are listed as follows.

1. Profit Ratio Analysis (PRA) - To prioritize the products based on profitability of the products.
2. Critical Value Analysis (CVA) - To do customer focused product prioritization.
3. Analytic Hierarchy Process (AHP) - To evaluate a set of vendors and customer zones.
4. Integer Linear Programming (ILP) model - To allocate a set of products to a set of vendors optimally, by maximizing preference weightage.
5. Multi-objective optimization model - To optimize simultaneously by minimizing the procurement cost and maximizing the preference weightage.

2.8 CONCLUSION

In this chapter, types of vendors and vendor-related issues are discussed. Observations made from previous research work on vendor evaluation and selection, are highlighted. The chapter ends with the need for this research, research problem, research objectives and research methodologies.