A Multi-Criteria Group Decisionmaking Model for Supplier Rating

AUTHORS

C. Muralidharan

is a reader in the Department of Production Engineering at Annamalai University in Chidambaram, India.

N. Anantharaman

is professor and head of the Department of Production Engineering at Annamalai University in Chidambaram, India.

S.G. Deshmukh

is a professor in the Department of Mechanical Engineering at the Indian Institute of Technology, Delhi in New Delhi, India.

SUMMARY

An important problem in decision analysis is the evaluation of the difference between two or more different rankings for a set of alternatives. A novel model based on the aggregation technique for combining group member's preferences into one consensus ranking is suggested in this article. The model developed may be used to develop consensus and evolve ranking of alternatives. The application of the model is demonstrated through a case for supplier rating. The advantages of the proposed approach are also highlighted.

EXAM ALERT
Module 1

INTRODUCTION

During the last decade, the business environments all over the globe have undergone and experienced significant change. In particular, the purchasing environment has become one of the most crucial elements in establishing the value-added contents for products and services and hence has become a vital determinant to ensure the profitability and survival of business organizations. Materials represent a substantial part of the value of products, and for a majority of industries, represent more than 50 percent of the sales price. The key objective of the purchasing department is to purchase the right quality of material in the right quantity from the right source at the right time and at a reasonable price. As implied by the above statement, quality, cost, and on-time delivery are the three most important criteria in supplier selection. Traditionally, suppliers are selected on their ability to meet the quality requirements, delivery schedule, and price offered. However, in modern management, one needs to consider many other factors with the aim of developing a long-term supplier relationship. With the increase in use of quality management and Just-In-Time (JIT) concepts by a wide range of firms, the supplier selection decision has become even more critical.

The broad objectives of this article are to:

- Understand the strategic operating decision area of the supplier selection process
- Analyze the impact of supply sources on the goals of an organization
- Enhance understanding of the importance of the interactive flow of inputs from a cross-section of the organization in evaluating sources from a strategic perspective
- Develop a model to aid decision makers with varying degrees of importance to reach consensus in rating alternative suppliers

The authors would like to thank anonymous referees for their valuable comments which have helped in improving the format and content of this article.

LITERATURE REVIEW

The explicit consideration of multiple, conflicting objectives in a decision model has made the area of multiple criteria decisionmaking (MCDM) very challenging. A comprehensive list of existing group decisionmaking methodologies and synthesizing mechanisms based on voting and ranking procedures mostly suitable for problems involving a discrete number of alternatives can be found in Hwang and Lin (1987). Jelassi et al. (1990) reviewed formal models for group decisionmaking and negotiation; discussed relationships, similarities, and differences between group decisionmaking and negotiations; and described some examples of conceptual frameworks and actual implementations of group decision support systems (GDSS) and negotiation support systems. Iz and Gardiner (1993) performed an extensive survey and analysis of the MCDM techniques and related GDSS that have been tested in cooperative decisionmaking situations. Matsatsinis and Samaras (2001) have reviewed past approaches, applicability, importance, and current and future trends of multi-criteria decision aid theory on group decisionmaking and negotiation situations. Guitouni and Martel (1998) have drawn a conceptual framework for articulating tentative guidelines to choose an appropriate MCDA method. Despite the increasing popularity of MCDM methods, the performance of such procedures when used by multiple decision makers remains unproven (Iz and Jelassi 1990). In a typical group decisionmaking situation, the preferences of the group members are expected to vary from each other. Consequently, determining the best alternative solution to the multi-objective problem requires aggregation of individual preferences (Iz and Jelassi 1990). There is a plethora of methods available for determining the ranking of a set of alternatives in terms of a set of decision criteria.

Various researchers have studied the problem of combining individual preferences into a group choice (for example, Cook and Kress 1985; Ali et al. 1986). Unlike the theoretical preference aggregation rules that require explicit knowledge of the decision makers' utility function, the consensus formation model of Cook and Kress (1985) needs only implicit utility information from the decision makers' through ordinal ranking of a set of solutions. They proposed a network model for deriving the optimal consensus ranking that minimizes disagreement among a group of decision makers. Ali et al. (1986) presented an integer programming approach for consensus ranking. While these techniques are complex, Beck and Lin (1983) have developed a procedure known as minimum regret heuristic to arrive at a consensus ranking. Aczel and Saaty (1983) illustrated the application of Analytic Hierarchy Process (AHP) in a group decisionmaking environment. Ray and Triantaphyllou (1998) have developed an analytical approach for calculating the number of agreements for rankings of different sizes. Cook and Kress (1991) presented a model for evaluating a set of alternatives on the basis of multiple criteria, where the information provided is ordinal. The model presented for obtaining a composite ranking of alternatives builds on the principles of the Data Envelopment Analysis (DEA) method. Iz and Jelassi (1990) have measured the individuals preferences of group members through an ordinal ranking scheme and used it for determining the final ranking of alternative solutions that will cause minimum regret among decision makers using goal programming as a modeling tool. Most of the methodology proposed treats all the individuals as equivalent when undertaking the aggregation procedure. Obviously, some individuals are more important to an organization than others. Decisions affecting the entire national economy, such as energy policy decisions, is an example. In such decision situations, the criteria to be considered are highly diverse and no single expert can be expected to have "expertise" to comment on all such criteria. Thus, a clear extension of this methodology is to weight the various individuals by their importance, and then to conduct the synthesis to generate the rankings.

Despite the theoretical developments in preference aggregation, most of the real-world applications in this area involve theoretically less rigorous but more practical aggregation procedures. In this regard, several approaches have been used to support deliberations within groups. But the emphasis in these efforts has been either on (Islei and Lockett 1991) (1) facilitating the process of quantifying preferences of individual members and then following "whatever ground rules there are for reaching a single judgment" or on (2) investigating behavioral patterns as they develop in the group process.

In this article, a model is developed to reach consensus ranking of the group. The following section explains the importance of the MCDM in supplier rating and how the AHP may be useful in such a situation, followed by the methodology adopted. Finally, the group consensus by the application of the model is demonstrated.

SUPPLIER RATING

Mohanty (1990), in his extensive survey, has identified that nearly all materials managers view the selection of suppliers as the most important decision problem in today's competitive business environment. Suppliers are considered the best intangible assets of any organization. Suppliers have varied strengths and weaknesses that require careful assessment before order placement. It can be argued that it is extremely difficult for any one supplier to excel in all dimensions of performance (Verma and Pullman 1998). Suppliers have to satisfy minimum overall performance standards, but one of the scheme's objectives is to improve these continually. A number of conceptual and empirical articles on supplier selection have appeared. The empirical articles by Chapman

Table I

COMPARISON OF VARIOUS SUPPLIER RATING METHODS

Method	Advantages	Limitations
Categorical	1. Can include both qualitative and quantitative criteria. 2. Easy implementation. 3. Lowest implementation cost. 4. Requires minimum data.	1. Equal weight to all criteria. 2. Subjective.
Weighted point plan	1. Simple to understand. 2. Easy implementation.	1. Subjectivity of the decision maker in the identification of weights. 2. Assumption of ordinal scale as cardinal scale. 3. All factors need to be expressed in standardized or normalized units.
Mathematical programming	1. Can guarantee optimum solution. 2. Objective evaluation.	1. Difficult to include multiple decision makers. 2. Requires arbitrary aspiration levels. 3. Objective function coefficients should be determined prior to making the model. 4. In LP/MIP, many objectives are regarded as constraints, since their formulations allow only one objective function.
Cost approach	1. Cost-control oriented. 2. Bias can be eliminated. 3. Allows to quantify internal production problems caused by supplier. 4. Objective evaluation.	1. Requires lot of data. 2. Complex approach requiring a comprehensive cost accounting system to generate the precise cost data needed. 3. High implementation cost. 4. Can deal with only relatively small number of criteria. 5. May not be useful in comparing supplier performance because of the difficulties inherent in translating all aspects of supplier performance into precise cost figures. 6. Difficult to include multiple decision makers.
Vendor profile analysis (VPA)	1. Incorporates uncertainty in the assessment procedure.	1. It may not be able to structure complex problems. 2. Giving weights to various criteria is subjective. 3. The interpretation of the resulting distribution of scores happens by judging modus, variance, and overlap.
Statistical	1. Uncertainty can be incorporated.	1. Assumption of distributions. 2. Difficult to grasp as they involve complex computational features.
Vendor performance index (VPI)	1. Each criterion can be measured in its own units. 2. Single measure of supplier performance. 3. Can be used as an assessment criterion for continuous evaluation.	1. Rating and weighting system is subjective. 2. It is impossible to obtain a zero score on a criterion since division by zero is not defined.
Standardized unitless rating (SUR) index	1. Single measure of supplier performance.	1. Rating and weighting system is subjective. 2. Cannot use the score for continuous assessment.
Proposed method	1. Inclusion of multiple decision makers. 2. Can include both qualitative and quantitative criteria. 3. Structuring of complex problems. 4. Can be conducted either by face-to-face meeting or by postal questionnaire.	1. Subjectivity in rating the suppliers.

(1993), Choi and Hartley (1996), and several others have evaluated the relative importance of quality, cost, delivery performance, and other supplier attributes. A systematic overview of such criteria is given by Weber et al. (1991) and Yahya and Kingsman (1999). Weber et al. (1991) reviewed 74 papers on supplier selection in the academic literature in terms of the criteria used. They found that net price was the most discussed criterion, followed by delivery and quality. The other criteria (other than quality, delivery, and price) are regarded as less important. They still play a role, however, in the supplier rating exercise. They have value because each supplier must achieve some minimum level of attainment on them to be registered in the scheme. The conceptual articles emphasize that managers should not select suppliers based on low cost only but should consider quality, delivery performance, and other attributes.

Additionally, the conceptual articles have suggested a number of approaches to assist in supplier selection. Some of these include: categorical method, weighted point plan, cost-ratio method (Timmerman 1986), vendor profile analysis (Thomson 1990), vendor performance index (Willis et al. 1993), standardized unitless rating (SUR) method (Li et al. 1997), cost approach (Smytka and Clemens 1993; Ellram 1995; Roodhooft and Konings 1996; Degraeve et al. 2000), outranking approach (Boer et al. 1998), multi-attribute utility theory (Min 1993), statistical approach (Verma and Pullman 1998), Analytic Hierarchy Process (Nydick and Hill 1992; Mohanty and Deshmukh 1993; Partovi and Hopton 1994; Barbarosoglu and Yazgac 1997; Noci 1997; Muralidharan et al. 1999; Yahya and Kingsman 1999; Muralidharan et al. 2001; Lee et al. 2001), and Mathematical Programming (Cook and Johnston 1992; Weber and Current 1993; Chaudhry et al. 1993; Sadrian and Yoon 1994; Current and Weber 1994; Rosenthal et al. 1995; Weber and Desai 1996; Degraeve and Roodhooft 1998; Weber et al. 1998; Jayaraman et al. 1999). Table I gives an overview of the supplier rating approaches.

Timmerman (1986) proposed the cost-ratio method. This method collects all costs related to quality, delivery, and service and expresses them as a percentage of unit price. Weighted point plan (Timmerman 1986) quantifies the factors with relevant weights and then rates potential suppliers according to these weighted factors. Thomson (1990) proposed vendor profile analysis (VPA) to reduce the uncertainty innate to the rating mechanism. Thomson (1990) took into account the errors and uncertainties in scoring suppliers' performance on the criteria. He argued that "at best, for a given criterion, decision makers may be able only to accurately appraise a performance range within which an individual vendor's actual performance may fall." The Monte Carlo simulation method is used to randomly generate scores within these ranges to produce an overall rating for the supplier. This is done repeatedly and the average of the repetitions is used as the rating for that supplier.

Willis et al. (1993) have used the modified "dimensional analysis" model, where a series of pairwise comparisons are made among suppliers using a vendor performance index (VPI). Li et al. (1997) have proposed a fuzzy set methodology by introducing the SUR index as an alternative to VPI in which they describe the disadvantages of the VPI. The SUR index takes the inconsistency of the evaluator into account for each qualitative criterion. For qualitative criteria, a two-directional consideration is used instead of a one-directional approach, which results in only a single score.

Smytka and Clemens (1993) have developed a total cost approach in which they assess "risk factors" on a go/no-go basis. Then they developed rates on several "business desirable factors" such as delivery performance, and used them in the supplier selection process. Ellram (1995) and Roodhooft and Konings (1996) developed the link between the selection of suppliers and activity-based costing. Degraeve et al. (2000) have used the concept of total cost of ownership (TCO) as a basis for comparing the relative efficiency of different supplier selection decision models. The TCO quantifies all costs associated with the purchasing process throughout the entire value chain of the firm.

Boer et al. (1998) have used an outranking approach, ELECTRE I, and Min (1993) has used multi-attribute utility theory for supplier rating. Verma and Pullman (1998) examined the difference between managers' rating of the perceived importance of different supplier attributes and their actual choice of suppliers in an experimental setting. They used two methods: a Likert scale set of questions, to determine the importance of supplier attributes, and a discrete choice analysis experiment, to examine the choice of suppliers.

Mohanty and Deshmukh (1993) have illustrated the use of AHP for supplier evaluation with an illustration. Partovi and Hopton (1994) have applied AHP for supplier evaluation and order splitting. Noci (1997) suggested a supplier selection procedure according to an environmental viewpoint using AHP. He has compared categorical method, weighted point method, vendor profile analysis, and AHP based on the type of information that can be included in the selection procedure, the completeness and objectivity of the assessment procedure, and concluded that AHP is a better technique for supplier rating. Yahya and Kingsman (1999) validated 25 criteria for assessing a supplier's performance based on the responses from senior managers in an engineering company. The authors have concluded that over 30 years, the basic criteria for supplier selection are little changed and there may be some variations in terms of the ranking of these criteria. They have applied AHP for assigning weights to various criteria such as quality, delivery, etc., and used a five-point Likert scale for scoring suppliers

on these criteria in a group decisionmaking situation. But it is not clear how they have combined the individual's rating of the supplier into group aggregation. Muralidharan et al. (1999) have applied control chart logic for evaluation of suppliers using AHP. Muralidhran et al. (2001) used the confidence interval approach for continuous assessment of suppliers.

Various authors have used mathematical programming models. These models can be subdivided into:

- Linear programming (LP)
- Mixed integer programming (MIP)
- Goal programming (GP)/multi-objective programming (MOP)

Cook and Johnston (1992) overcame the problems of weighted point plan by ignoring the supplier rating issue. They modified the problem to consider directly the question of how to choose and how to allocate business among suppliers. They developed a LP model based on the data envelopment analysis (DEA) technique. Chaudhry et al. (1993) have developed linear and binary MIP models with price breaks that provide unifying frameworks for models of supplier performance measures. Weber and Current (1993) have used multiobjective MIP for supplier selection. A fixed number of suppliers are introduced as a constraint and they propose price, delivery, and quality objectives. The authors used a value path analysis to graphically display the results. Weber and Desai (1996) have proposed DEA for evaluation of suppliers that were already selected. A parallel axis analysis algorithm was used to identify alternative paths, which inefficient suppliers can use to become efficient contenders for some portion of the firm's business. They applied DEA to construct an index of "relative vendor efficiency" to operationalize the concept of supplier performance. Current and Weber (1994) have demonstrated that the supplier selection problems may be formulated within the mathematical constructs of facility location modeling. Their intention is to demonstrate the similarities between supplier selection problems and facility location problems. They formulate the single plant location problem as a supplier selection model minimizing the sum of fixed costs and "actual purchasing" costs. Sadrian and Yoon (1994) have proposed a MIP model that is focusing on the modeling of business volume discounts. Rosenthal et al. (1995) have developed a MIP model in which suppliers offer discounted prices for bundled products. The same quality and delivery constraints as in Chaudhry et al. (1993) are added for every item and the methodology used by Sadrian and Yoon (1994) is followed, but multi-criteria extensions are discussed as well. Degraeve and Roodhooft (1998) have used a mathematical programming model using activity-based costing information to determine optimal order splitting among suppliers on the basis of the different costs associated with the purchasing decision. Weber et al. (1998) have extended the Weber and Current (1993) and Weber and Desai (1996) studies. They described three approaches for the selection and negotiation with suppliers that are not selected. Jayaraman et al. (1999) proposed a mixed integer programming (MIP) approach to simultaneously decide the set of suppliers and order quantity allocations among them.

PROPOSED MODEL

Even though the MCDM models for supplier evaluation have been very well documented, only a few models use multiple decision makers in the analysis (for example, Muralidharan et al. 1999; Yahya and Kingsman 1999; Muralidharan et al. 2001). Among the he different MCDM models, AHP has aroused considerable interest in practitioners and researchers in recent years. AHP was developed by Saaty (1980). General methodology, analytical-mathematical treatments of AHP have been presented by Saaty (1980) and Harkar and Vargas (1987). The main advantage of AHP is its ability to handle complex and ill-structured problems such as supplier rating, which cannot be usually handled by rigorous mathematical models (Mohanty and Deshmukh 1993). In addition to simplicity, ease of use, flexibility, and intuitive appeal, the ability to mix qualitative and quantitative criteria in the same decision framework has led to AHP's power and popularity as a decisionmaking tool. In addition to this, the estimate of the consistency to expert judgments and its popularity in group decisionmaking are the other advantages of AHP. Three features of the AHP differentiate it from other decisionmaking approaches (Wedley 1990; Vargas 1990):

- Its ability to handle both tangible and intangible attributes
- Its ability to structure the problems in a hierarchical manner to gain insights into the decisionmaking process
- Its ability to monitor the consistency with which a decision maker makes judgment

Given the advantages of AHP, a novel model based on the principle of aggregation is proposed. A step-by-step procedure for the proposed model is presented below.

Step 1: Identify the Active Participants to be Involved in Decisionmaking

Many purchasing decisions are taken or at least influenced by several actors (Weele 1994). The various individuals may be drawn from different functions of the organization such as production, quality control, maintenance, etc. These people can influence or can be influenced by the organizational decisionmaking process. The functional heterogeneity in such multifunctional teams is potentially an asset and the advantages of such teams are explained in (Pelled and Adler 1994). These people should be selected based on factors such as their experience and knowledge about various business functions of the company. In group settings, all participants

Table II

EXPLANATION OF ATTRIBUTES FOR SUPPLIER EVALUATION

S.No.	Attribute	Explanation
1	Quality (Q)	Inspection methods Percentage rejections Following TQM, JIT practices Product performance (reliability, accuracy)
2	Delivery (D)	Delivery speed (leadtime) Dependability (meeting delivery schedules) Transport costs Flexibility in delivery schedule
3	Price (P)	Quantity discount Cost
4	Technical capability (TC)	Technical problem-solving ability Range of products supplier could make R&D facilities Technical manpower availability
5	Financial position (FP)	Liquidity Credit rating policy
6	Past performance attitude (PPA)	Honesty Attitude to improve operations Cooperation in scheme Response time
7	Facility (F)	Machinery Infrastructure Capacity utilization
8	Flexibility (FL)	React to changes in volume React to changes in product mix React to changes in modifications in design
9	Service (S)	After-sales service Availability of spare parts

Table III

EXPLANATION OF ATTRIBUTES FOR INDIVIDUAL EVALUATION

S.No.	Attribute	Explanation
1	Knowledge (K)	Awareness of the person about the suppliers, about the rating system and the products supplied by them Basic educational qualifications
2	Skill (S)	Problem-solving capability (ability of a person in understanding critical problems (both suppliers' and company's) in least possible time) Time taken in responding with a solution to the problem which was put to him
3	Attitude (A)	Commitment level (attitude in developing a supplier) Flexibility in approaching the problem (to adapt himself to the situation when inconsistent jobs were given to him) Positive problem-solving approach Reliability of the person Loyalty toward the company
4	Experience (E)	Experience of the person in the field of supplier rating Work experience in the company

Table IV

COMPARISON OF FACTORS ON WHICH THE INDIVIDUALS ARE TO BE WEIGHTED

	K	S	A	E	Priority Weights
K	1	3	4	3	0.490
S	1/3	1	4	3	0.283
A	1/4	1/4	1	1/3	0.076
E	1/3	1/3	3	1	0.152

Table V

COMPARISON OF INDIVIDUALS ON SKILL (S)

Individuals	P1	P2	P3	P4	P5	P6	P7	Priority Weights
1	1	3	1/5	1/3	1/3	1/6	1/5	0.047
2	1/3	1	1/7	1/5	1/4	1/7	1/7	0.027
3	5	7	1	3	4	1	1	0.244
4	3	5	1/3	1	2	1/3	1/3	0.107
5	3	4	1/4	1/2	1	1/4	1/4	0.079
6	6	7	1	3	4	1	1	0.251
7	5	7	1	3	4	1	1	0.245

Table VI

OVERALL WEIGHT OF THE INDIVIDUALS ON THE ATTRIBUTES

		Individuals						
Attribute	Weight	P1	P2	P3	P4	P5	P6	P7
Knowledge	0.490	0.068	0.039	0.299	0.165	0.024	0.106	0.299
Skill	0.283	0.047	0.027	0.244	0.107	0.079	0.251	0.245
Attitude	0.076	0.131	0.023	0.131	0.072	0.041	0.301	0.301
Experience	0.152	0.067	0.037	0.297	0.297	0.022	0.111	0.169
	Total weight	0.066	0.034	0.271	0.162	0.041	0.163	0.263

do not have equal expertise about problem domain (Ramanathan and Ganesh 1994). Where conflicting judgments are unlikely to be resolved through group consensus, stakeholders may be weighted according to their power to influence the outcome (Saaty and Alexander 1989). Once the individuals are identified depending upon the various attributes, the weights to the individuals may be determined by using AHP.

The sequential procedure for understanding the general structure of the AHP model is explained below (Mohanty and Deshmukh 2001):

1. Create a hierarchy of the factors and alternatives by breaking down the problem into a hierarchy of decision elements.
2. Provide judgments about the relative importance of each of the factors and alternatives using the pairwise comparison of decision elements.
3. Determine whether the judgments satisfy a "consistency test." If they do not, go back to (2) and redo the pairwise comparisons.
4. Calculate the relative weights for various decision elements.
5. Aggregate the relative weights to obtain composite weights and hence obtain rankings for the decision alternatives.

Step 2: Identify the Significant Factors/Attributes Involved in Decisionmaking

Brainstorming sessions involving various individuals drawn from different functions could be used for this purpose. The participants (individuals) must identify those factors/criteria that will enable the organization to achieve the management's objectives, i.e., to select the best supplier. Several factors may be identified at this stage, and a diversity of views may be represented. However, some of the factors may not be significant in achieving the overall objective, and a way to filter out the insignificant factors is required. Since there are bound to be conflicts in what participants perceive as important to achieving the objective, a group leader may resolve these conflicts. The group leader may apply several strategies such as brainstorming, nominal group technique (NGT), etc., to control the process and identify and eliminate the insignificant factors. As the number of factors grows, it becomes difficult to comprehend

Table VII

GUIDELINES FOR SUPPLIER ATTRIBUTE

Point	Grade	Description
5	Exceptional	Demonstrates substantially excellent performance, and has been in the excellence category for last 12 months
4	Excellence	Exceeds company's and customers' expectations, demonstrates extra effort, and is superior to vast majority of suppliers
3	Good	Meets the company's expectations
2	Acceptable	Meets company's minimum requirement
1	Poor	Does not meet the company's and customers' minimum acceptable level

Table VIII

RANKING OF SUPPLIERS

	Suppliers					
Individuals	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
P1	5	6	1	3	4	2
P2	3	4	1	6	5	2
P3	1	2	3	5	6	4
P4	1	2	6	5	4	3
P5	2	6	3	1	4	5
P6	3	1	5	2	4	6
P7	4	2	6	5	1	3

Table IX

WEIGHT OF SUPPLIERS BASED ON RATING BY INDIVIDUAL 1

Suppliers																Total	Weight
S1	1	0	0	0	0											1	1/15 (0.067)
S2	0					0	0	0	0							0	0
S3		1				1				1	1	1				5	5/15 (0.033)
S4			1				1			0			1	0		3	3/15 (0.2)
S5				1				1			0		0		0	2	2/15 (0.133)
S6					1				1			0		1	1	4	4/15 (0.267)
Total																15	1.000

and compare all of the choices at one time. The essence of this is to avoid information overload.

Step 3: Identify the Alternatives to be Rated

To limit and to identify the number of alternatives, a similar procedure as explained in Step 2 may be followed.

Step 4: Rank the Alternatives

Using the five-point Likert scale, the individuals may rate the alternatives on each of the attributes. From the rating, obtain the ordinal ranking of the alternatives. The preference order data supplied by a respondent will be in the form of priorities to be given to the alternatives. Such responses can be in the form of binary pairwise comparisons (choice *i* is preferred to choice *j*), or in the form of priority vector (alternative 1 gets a rank of 2, alternative 3 gets a rank of 7, etc.). For the purpose of the development in this article, it is assumed that the individuals supply the latter type of information, i.e., the individual preferences of group members measured through an ordinal ranking scheme is used in determining the final ranking of alternatives. A desirable feature of this ordinal ranking scheme is its ability to capture the intensity of a decision makers' preferences.

Step 5: Obtain the Consensus Ranking

By applying the proposed model, obtain the consensus ranking of the group for the alternatives, by summarizing the individual preferences. The application of the model developed is explained with an illustration in supplier rating.

Table X

OVERALL WEIGHT OF SUPPLIERS BASED ON THE GROUP

		Suppliers' Weights					
Individuals	**Individual's Weight**	**S1**	**S2**	**S3**	**S4**	**S5**	**S6**
P1	0.066	0.067	0	0.333	0.2	0.133	0.267
P2	0.034	0.2	0.133	0.333	0	0.067	0.267
P3	0.271	0.333	0.267	0.2	0.067	0	0.133
P4	0.162	0.333	0.267	0	0.067	0.133	0.2
P5	0.041	0.267	0	0.2	0.333	0.133	0.067
P6	0.163	0.2	0.333	0.067	0.267	0.133	0
P7	0.263	0.133	0.2	0	0.067	0.333	0.267
Total composite weight		0.233	0.227	0.107	0.117	0.147	0.168
Rank		1	2	6	5	4	3

A CASE

The proposed model is applied in a case situation. The company under question is a leading organization manufacturing bicycles. The engineering products consisting of a subassembly are to be supplied by suppliers (S1 to S6) and are to be evaluated by individuals (P1 to P7) drawn from various functions such as purchasing, stores, and quality control, on multiple attributes such as quality, delivery, etc., as given in Table II. The explanation for the attributes is also provided in Table II. The attributes and their explanations on which the individuals are to be rated are provided in Table III. Table IV gives the priority weights of the attributes on which the individuals are to be weighed using the pairwise comparison of attributes (using Saaty's 9-point scale) with respect to the overall objective of the management (Saaty 1980). Table V gives the pairwise comparison of the individuals with respect to skill and also their priority weights. Similarly, the priority weights of all the individuals on other attributes were obtained and are given in Table VI. The weights of the attributes on which the suppliers are to be rated were also obtained using AHP. The AHP exercise was carried out by the group leader in consultation with the management and maintaining the principle of anonymity. Estimation of weights has been recognized as one of the main problems. In AHP, the usual procedure is to create a hierarchy to judge the importance of the members and use the judgments of a single person, who may be called as supra decision maker, to compute the members' weightings. This procedure requires the existence of such a supra decision maker, who may not be available, or may not be acceptable to the group members. In the absence of such a supra decision maker, the weights have to be determined from among the group members through a participatory approach. Usually, the participatory approach relies on frequent interactions among the group members for setting the weights (Saaty 1989). However, such interactions may not be possible when judgments are collected through questionnaires. In such a case, weights have to be computed in an objective way from the opinions expressed by all the group members (Ramanathan and Ganesh 1994).

Once group members have reached agreement on the framework, they generally seek to quantify their preferences without recourse to the other participants (Islei et al. 1990). In other words, an emphasis on consensus through all stages of the decision process does not appear to be particularly desirable (or even feasible, for that matter). Individual assessments are a basis on which agreement of options is reached. The seven individuals were asked to rate the suppliers' performance individually on each of the attributes using the five-point Likert scale (Table VII). The weight of each factor is multiplied by the performance score that is assigned. Finally, these products are totaled to determine a final rating for each supplier. Mathematically, the supplier rating is equivalent to the sum of the product of each factor weight and supplier performance score of each factor. This process is carried out by all of the individuals. The ordinal ranking of the suppliers is provided in Table VIII. In many instances, the ranking is of the ordinal rather than the cardinal type. That is, the information available to the ranker is of such a nature that only an expression of preference (not degree of preference) can be given. Rank orders are very useful when reviewing overall developments and searching of patterns (Islei and Lockett 1991).

For weighting various individuals by their importance, and then to conduct the synthesis to generate the rankings, the weighted arithmetic mean method (WAMM) (Aczel and Saaty 1983) may be applied. Even though AHP is applied successfully in practice, there are some limitations when it is applied to group decisionmaking, such as:

1. The number of pairwise comparisons required to develop the judgment matrix (Millet and Harker 1990; Weiss and Rao 1987). These comparisons accumulate as follows in the decision hierarchy. Level 1 is the top of the hierarchy

and represents the final goal or objective. At Level 2, where n1 attributes are compared, these are 1/2 n1 (n1 – 1) comparisons required to complete the judgment matrix; Level 3, where n2 attributes are compared, consists of n1 [n2 (n2 – 1)/2] comparisons, and so on until the last level is reached. Moreover, in case of multiple decision makers (M), at each level the number of pairwise comparisons gets multiplied by "M."

2. It may be noted that for effective results, AHP has to be conducted on the basis of face-to-face study and discussion. It cannot be carried out effectively as a postal questionnaire (Yahya and Kingsman 1999). This is because a maximum interaction is necessary to ensure respondents understand their functions and how to make comparisons among criteria; all information on definitions, questions, and procedures must be made clear to respondents. Training is usually required to ensure that respondents understand the definitions and guidelines, especially on how to make the comparison process, given its critical role in the AHP study. Allowing enough time for respondents to complete the comparison matrix is important to ensure the success of the study.

Having obtained the ordinal rankings, should members aggregate their estimates and preferences to some total? If so, how should the group do these aggregations: by some voting rule, averaging or aiming at some ideal solution? Taking an average is the most obvious thing to do for finding consensus ranking, but there are several problems with this approach. For example, if the relative performance measures are ratio-scale numbers, then their average may be meaningless theoretically (Saaty 1986). Even though the individuals' ranking may differ (Table VIII) and decision makers desire for consensus ranking, a model is developed and applied here to develop the final ranking of the alternatives (suppliers) as a whole. Table IX shows the necessary calculation for the model to obtain the priority weights of the suppliers based on the first individual's rating. Table IX uses the pairwise comparison of the ordinal ranking of the suppliers (from Table VIII) and, for example, when supplier 1 is preferred over supplier 2, a numerical value 1 is assigned to supplier 1 and 0 is given to supplier 2. Similarly, all of the other values are entered in Table IX based on the first individual's ordinal ranking. The weight of individual 1 preferring a supplier is given in the last column. Similarly, all of the individuals preferences for the suppliers are given in Table X. The overall weight obtained by each supplier is also given in Table X. Supplier 1 is rated first (overall weight = 0.233), followed by supplier 2 (0.227), and then supplier 6 (0.168), and so on. The suppliers are rated in the following order: S1>S2>S6>S5>S4>S3.

Islei and Lockett (1991) have suggested that the accuracy of numerical results matters very little as long as they provide a reasonably robust representation of the decision maker's preferences. In order to develop an effective framework, participation and agreement by all (or at least most) members is essential. These ensure that ownership of the effort is shared and thus commitment is likely to increase. This approach utilizes the potential of a group setting through sharing in the model development process. Additionally, it enables the team to appreciate differing perspectives by carefully assessing and examining individual preferences prior to aggregation. When individuals (or subgroups) differ systematically among themselves with respect to the variables of interest, such information is often lost when pursuing a consensus approach too narrowly. If such differences do exist, then averaged information will be an artifact, not accurately reproducing the characteristics of the group (Islei et al. 1990).

A structured procedure for aggregating individual preferences is hypothesized to make a difference in the efficiency of a MCDM technique when used by multiple decision makers. The results of the study may be in favor of a decision support aid that includes a formal preference aggregation step. The subjects may also have more confidence in their final solutions with the formal procedure than with the informal approach. The consensus ranking vector may be presented to the group to facilitate further group discussion. Support for group decisions has to be flexible so as to respond to the way practitioners approach a problem while, at the same time, enabling them to improve elements of team performance. The proposed method has the advantage of being a more formal and systematic method, for multicriteria/multiple decision makers. It allows for a wider range of options as the process can be done either by face-to-face study or through mail questionnaire and it requires minimal data requirements. In many applications, although rank orders may be all that are required, more detailed information is necessary to obtain an insightful understanding of the relation between individual preferences and the group decision. Ordinal rankings are generally too coarse a measure to explain crucial process developments (for example, contingent trade-offs).

CONCLUSIONS

The majority of real-world decisionmaking problems involve multiple decision makers. However, the comprehension, analysis and support of the process becomes increasingly difficult due to the ill-structured, dynamic environment and the presence of multiple decision makers, each one of them having his or her own viewpoint on the way the problem should be handled and the decision to be made. The role of leadership, the influence of group formation, and analysis of disagreements

are also important topics. Given the complexity of these issues, it cannot be expected that there will ever exist a panacea to cope with all multi-criteria/multi-actor situations. Rather, a large number of competing models and methods (each with its own merit) is probably the most feasible approach to the situation. The comparison of conflicts in rankings is a challenging area for both practitioners and academicians. It has much promise for applications in such diverse areas as negotiations, corporate executive succession, and selection of "like-minded" or contrawise, diverse groups. The process is designed to facilitate compromise among decision makers rather than guarantee convergence to group optimum solution. Consensus was important for many aspects of the decision process, but would have acted as an artifact if used as a means for establishing aggregate preferences. In retrospect, the decision process is most valuable in that it enables the group to identify and better appreciate the differences and commonalities of their judgments. It thus provides a common framework in which individual assessments could be established without constraints, and subsequently examined and compared in some detail. As for group decisionmaking, research to date indicates the importance of adopting a participative and flexible approach that, at the same time, allows the group to explore its differences of opinion. Successful applications are usually based on simple and robust methodologies that are relatively easily grasped by the decision maker. The results show how such models can identify differences within organizations. This capability may enable the group to focus on critical aspects and to go forward without the need for a (unattainable) consensus.

The results presented in this article have important implications for the operations strategy and supply chain management research. The analysis and results presented above have demonstrated that the methodology presented is a useful and practical method for carrying out supplier rating for a commercial organization.

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Applicants must be doctoral candidates who are pursuing a Ph.D. or D.B.A. in purchasing, business, logistics, management, economics, industrial engineering, or related fields. Applicants must be enrolled in accredited United States universities to be eligible for the grant. **No exceptions are made to these eligibility requirements.**

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2. Official transcripts from the candidate's current university.
3. Proposal abstract, maximum 25 pages, including a literature search and a research design. The proposal must specifically discuss:
   - Problem statement or hypothesis
   - Research methodology, including data sources, collection, and analysis
   - Significance/value of the research in purchasing/supply management
4. A letter from the candidate's major advisor, stating that the dissertation topic is acceptable.
5. Three letters of recommendation (one letter may serve as the letter requested in #4 above) from professors or administrators familiar with the applicant's research capabilities. The letters should be sealed independently within the application package.
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