A Decision Support System For Integration Of Vendor Selection Task

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Abstract

The purpose of this paper is to illustrate the usefulness of a particular decision support system, the Analytic Hierarchy Process (AHP), for developing and implementing integrated procurement systems. The purchasing decision support system (PDSS) proposed in this paper provides each participant involved in the purchasing process with a procedure to communicate their preferences and the reasons for those preferences. All of the participants' preferences may be aggregated to determine an overall preference, or in some cases, the results may simply be used to gain a better understanding of the values the individuals place on various attributes.

Introduction

The impact of purchasing decisions on a firm's profitability is generally accepted. It is also acknowledged that the growing diversity of available technologies frequently increases the number and variety of participants involved in purchasing decisions. The recognition of the importance and complexity of the purchasing function stimulated increased research in procurement management. One area of particular interest has been the integration of the procurement activities. Burt (1984) noted that the procurement of goods and services affected activities in many areas: marketing, finance, engineering, operations, production, and inventory control; and that the implementation of an integrated procurement system would result in increased profitability, productivity, and quality.

Many organizational purchases are viewed as being simple and routine and require only monitoring of continued satisfaction with the product's attributes (e.g., quality, delivery, price). However, all of a firm's simple and routine purchases were at some time "first-time" purchases. Thus, for many products, extensive searches and evaluations were made and inventory control models were developed which required only periodic updating. Although the use of a purchasing decision support system may be used for any type of purchase, it is most valuable for those purchases which are "first-time" purchases or for previously-purchased products which require specification modifications.

Since there are numerous questions to be answered during the purchasing process (e.g., design and performance specifications, time requirements), it is not unusual for many individuals in the organization to be involved in a "first-time" purchase or modified purchase. The number of individuals involved in the purchase decision process and their roles may vary dramatically. Hence, an effective purchasing strategy requires the cooperation and interaction of individuals in various functional areas and at various management levels during the purchasing process. The complexity of a purchase and the variety and number of participants reinforce the need for a system which will integrate the differing needs and objectives of the participants.

In one study of sixteen industrial firms' purchasing strategies, the researchers (Woodside and Vyas, 1987) reported that the individual participants in a purchasing decision usually made judgments and had specific preferences during, before, and after vendor search and evaluation. This study also reported that while the participants were able to express what criteria they used in their selection process, they did not typically discuss their methods with other members or how to combine their individual views or methods.

Knowledge of each individual's preferences and their behavior in specific buying situations can assist procurement managers in developing an integrated approach to purchasing. Researchers have compiled lists of the criteria which purchasers have used in the selection of vendors and have reported the relative importance of the criteria for specific buying situations (Dickson, 1966; Lehmann and O'Shaughnessy, 1974; Rao and Kiser, 1980). Others studies revealed which parties influenced the selection of a supplier and the degree of that influence (Choffray and Lilien, 1978; Thomas 1989). All of these studies have been helpful in creating an awareness of the variety olxselection factors and the extent of the influence of the participants. However, few studies have offered a method or model for initiating discussions about the criteria and methods the different participants in the purchasing decision use in their selection process. Nor has a simple, systematic method been suggested for practically combining the different criteria and decision rules to arrive at a formal set of procurement guidelines when there are multi-participants involved.

Since the effectiveness of a purchasing decision is a direct function of selecting the "right" vendor, the current study presents a purchasing example to illustrate the applicability of a decision support system (Analytic Hierarchy Process) in evaluating and selecting vendors.

Organizational Buying

Generally, organizational buying refers to a dynamic process consisting of a series of activities requiring the interaction of several members of an organization. Collectively, the participants in the purchasing process are referred to as the Buying Center.

Buying Center Structure

Since a Buying Center (BC) consists of all of the members of an organization which are involved in the buying process for a particular product, a BC's composition changes with the product being purchased. The number of members involved in a purchasing decision and the degree of their participation varies depending upon the specific buying situation. Numerous studies in the area of organizational buying behavior have emphasized the dynamics and complexities of such multiperson decision processes (Patchen, 1975; Spekman and Stern, 1979; Weigand, 1966). While some of the members of the BC may have specific preferences for a product or vendor, those preferences are based upon some criteria, and according to Woodside and Vyas (1987) the members are able to express those criteria when asked.

Purchasing Process

Purchasing is a multistage process encompassing a variety of activities. A review of the organizational buying literature indicates that the purchasing process has been divided into different stages by various researchers. One of the most widely accepted decision-process models was introduced by Robinson, Faris and Wind (1967). It consists of eight phases (Buyphases): (1) Anticipation or recognition of a problem and a general solution, (2) Determination of characteristics and quality of needed item, (3) Description of characteristics and quantity of needed item, (4) Search for and qualification of potential sources, (5) Requisition and analysis of proposals, (6) Evaluation of proposals and selection of supplier(s), (7) Selection of an order routine, and (8) Performance feedback and evaluation.

The purchasing decision support system (PDSS) presented in this paper could be applied at any phase of the process. However, for simplicity of the presentation, the PDSS example focuses on the actions occurring in Phase 6 of the Buyphases with only an occasional reference to the other phases. Consequently, a detailed description of how the purchasing preferences of the various members may be integrated to reach a common decision is provided only for the Evaluation of Proposals and Selection of Supplier phase. Since the example deals with choosing among alternatives, it is, of course, assumed that multiple proposals were received for evaluation.

Multiple Purchasing Criteria

Many criteria have been identified as contributing to the selection of a vendor. Typically, each study presents different buying situations for different industries, and thus, no "official" criteria list exists. Nevertheless, it is recognized that more than one criterion is used when selecting vendors resulting in a multicriteria decision situation. The fact that there is not a consensus as to exactly which criteria will be used for every buying situation emphasizes the need for a decision support system which readily allows the criteria to be changed by the requirements of the buying situation.

The problems associated with deciding how one vendor should be selected from a number of potential vendors has received considerable attention in the literature. A review of the literature indicates that numerous distinct criteria have been identified. Lehmann and O'Shaughnessy (1974) included 17 attributes in their study, and Dickson (1966) included 23 attributes. However, in several studies, the number of attributes is even larger. Rao and Kiser (1980) developed a list of 60 vendor attributes for evaluation purposes for the non-commercial sector. The sixty attributes were divided into six groups: (1) convenience-related, (2) economic-financial, (3) caliber-capability, (4) image-dependability, (5) inter-institutional relations, and (6) service-related. Payne (1970) grouped 52 evaluation factors under five categories: (1) technical or engineering, (2) manufacturing, (3) financial, (4) management, and (5) other. The use of the purchasing decision support system approach in selecting vendors could have been easily applied to any of these multicriteria studies. Regardless of the methods described in the studies, awareness of these and other vendor-attribute lists encourages members of a buying center to develop their own lists.

When employing a purchasing decision support system (PDSS), each individual member of the buying center may specify a list of criteria to be used in the decision process, each member may assign an importance value to each criterion, and each member may indicate an order of preference of vendors. The suggested purchasing decision support system also produces overall priorities for each individual BC member by analyzing their specific criteria, the importance they assigned to each criterion, and their vendor choices. Since an overall weight for each vendor is established for each BC member, the resulting evaluations may be reviewed individually or aggregated.

Since it is evident that many different criteria may be suggested by the different members, it was decided that for the sake of brevity in introducing the decision support system approach, our example would utilize only five of the most frequently mentioned criteria. Thus, five criteria (price, quality, technical service, delivery lead time, and delivery reliability) have been chosen to illustrate how the relative weights of the criteria and relative weights of the alternatives (vendors) are determined.

Regardless of the criteria identified or the weights assigned to the criteria, it is apparent that a thorough evaluation of vendors frequently requires the participants in the purchasing decision to consider numerous criteria simultaneously when selecting a vendor. Thus, most of the studies on evaluating vendors have focused on identifying the factors and their respective importance weights. Few studies have advanced a specific system or method for integrating the weights of the purchasing criteria across multiperson decision situations.

Evaluating multiple criteria simultaneously is not considered an easy task, but when the decision involves multiple participants, the complexity of the decision process increases. For example, if technical service is an important criterion in selecting a vendor, and if it were the only criterion, the purchasing participants would simply select the vendor with the best technical service. However, in most typical purchasing situations additional criteria, such as price, quality, and delivery, influence the decision. Although some disagreement might have been present among the participants as to which vendor had the best technical service, at least there was only one criterion to be considered. With the addition of multiple criteria, the participants may also differ as to the importance they each assign to a specific criterion. Regardless of what criteria or how many criteria are delineated by each member, a method for integrating the selection criteria is needed for evaluating the multiple vendors.

Multiperson Decision Situation

Not only are multiple criteria involved in the organizational purchasing process, but also multiple participants are involved. The degree of involvement and influence of the participants varies in each phase of the purchasing process (Laczniak, 1979; Lilien and Wong, 1984; Woodside, Karpati, and Kakarigi, (1978). For example, a user may be expected to exert more influence on the determination of the characteristics and quality of a needed item (Phase 2). During the evaluation of proposals and selection of the supplier (Phase 6), the purchasing agents may have more influence. Although the influence may vary in the different buyphases, the fact that other members are involved in the purchasing decision creates a multiperson-decision situation.

While some of the studies have attempted to combine the multiperson decision process with the buying process in order to understand which members of the Buying Center (BC) have the most influence during specific buyphases, others have studied the number of members involved for product specific situations. Irrespective of the purpose of the studies, the results indicate that the final purchase decision is a group decision.

Participants in the group decision not only are faced with the overall problem of selecting the "right" vendor, but also are faced with evaluating multi-attribute alternatives. One vendor's product may be superior with respect to quality, but the vendor may offer little technical support and service. Another vendor may provide exceptional technical support, but their delivery reliability is questionable. Since the participants must consider several criteria simultaneously when evaluating the potential vendors, they need a simple method to determine an overall worth of each vendor to ease comparisons.

Specifically, the participants need a method (purchasing decision support system) which will (1) be useful in determining the importance weights of the criteria that the individual members of the BC use in their vendor selection decisions, (2) be useful in combining the importance weights of the individual members to determine overall importance weights of the criteria, (3) be useful in examining how the relative importance of each criterion changes as the buying situation changes or the alternatives under evaluation become more complex, and allow management to determine if the importance weights are consistent with the objectives.

Since one vendor may be more desirable based upon one criterion while another vendor is preferred when another criterion is used, the complexity of the purchasing decision increases as the number of criteria increase. Any attempt to have multiple participants evaluate multiple vendors using multiple criteria without structuring the purchasing problem is extremely difficult. One decision support system that provides the needed structure and procedures for integrating the participants' preferences and criteria is the Analytic Hierarchy Process (AHP). This process involves decomposing the overall decision into subdecisions and evaluating the multicriteria and alternatives one or two at a time.

Decision Analysis

Most analytical methods using multiple criteria to evaluate alternatives are quite complex and require that the factors be directly measurable. For example, price is typically measured directly. However, measurement of technical service is frequently less direct; it might be measured in the availability of design engineers, background and experience of production engineers. Hwang and Yoon (1981) reviewed seventeen decision analysis techniques that a decision maker might use when evaluating multicriteria projects. They also concluded that while the techniques required the decision maker to trade off the importance of one factor against another, most of the mathematical models were complicated. Procurement management needs a method that is not only conceptually simple but also practical for integrating diverse viewpoints concerning criteria and vendors. The Analytic Hierarchy Process provides that method. A review of the literature indicates that AHP has been applied in many diverse situations (Cook, Falchi, and Mariano, 1984; Canada, Frazelle, Koger and MacCormac, 1985; Johnson, Srinivasan and Bolster, 1990).

The Analytic Hierarchy Process

The Analytic Hierarchy Process (AHP) is a quantitative approach designed to handle situations in which subjective judgments are a major part of the decision process. This approach is particularly suitable for selecting among competing alternatives that involve evaluation of multiple criteria. It provides structure for a problem, it provides a method for identifying the relative importance of the criteria, and it provides checks for consistency. Typically, the AHP is described in terms of four basic components of the AHP: (1) decomposition -- the breaking down of an overall problem into subproblems; (2) comparative judgments -- the use of pairwise comparisons to estimate the relative importance of various criteria; (3) synthesis of priorities -- the development of an overall estimate of the desirability of each alternative, and (4) consistency -- the determination that the judgments are consistent. For ease of explaining how to use AHP for purchasing decisions, these components are divided into five stages. These stages are illustrated in Figure 1 and provide the framework for explaining the example.

Vendor Evaluation Example

In order to demonstrate how the Analytic Hierarchy Process may be used to encourage communication and cooperation among purchasing participants and may be used to synthesize competing criteria and decision rules, an example is presented in a step-by-step manner.

Stage 1. Define the Problem and Relevant Factors.

The "Evaluation of Proposals and Selection of Vendor" Phase of the Purchasing Process was chosen to illustrate the use of the Analytic Hierarchy Process (AHP). For demonstration purposes, we will assume the item we are purchasing is a Computer Aid Drafting (CAD) computer system. Thus, the "defining the problem" portion of the first step corresponds to our setting a goal or objective of "selecting a vendor" from whom to purchase the CAD system. The "defining the relevant factors" portion corresponds to determining which criteria will be used to evaluate the vendors for this purchase. Each member of the buying center should specify all of the subjective and objective factors which might possibly affect their individual decision. The AHP permits the members to select different criteria. It is probable that all of the BC members would not furnish identical lists. It is also probable that each individual's perceived relative importance of the shared criteria would not be equal. However, the mere sharing of criteria lists encourages communication. Again, for simplicity of our example, we have chosen the criteria: quality, price, technical service, delivery reliability, and delivery lead time.

Stage 2. Develop a Graphical Hierarchy.

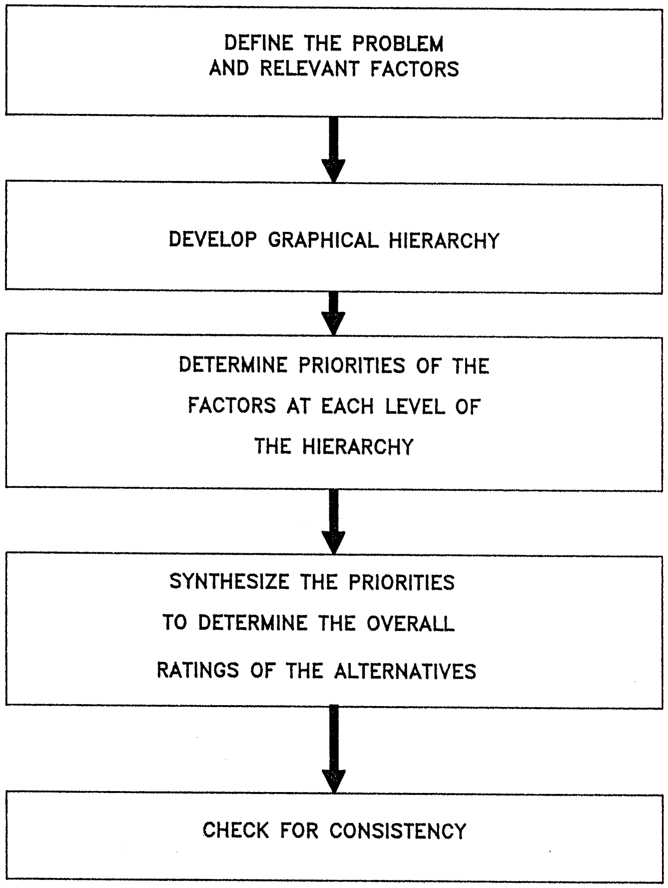
During the second stage, the goal, selection criteria, and alternative vendors are structured in a hierarchical manner that can be understood and evaluated easily. This is usually accomplished by a graphical representation. Although there is no single generic hierarchical structure, the structure consists of levels. The highest level represents the overall goal (e.g., selection of a vendor for purchase of a general purpose Computer Aided Drafting software package), and the lowest level includes the vendors under consideration. The intermediate levels of the hierarchy contain criteria and subcriteria under which each vendor will be evaluated. There may be one or more intermediate levels.

For most decisions, one would begin Stage 2 by recording the overall goal at level 1, and then proceeding to each succeeding level and recording the criteria and subcriteria. The intermediate levels may contain as many criteria and subcriteria as the members may elect to submit. The final level consists of the vendors who have submitted proposals. In simple cases, there may be only one intermediate level -- relevant criteria. For this

FIGURE 1

BASIC STAGES OF THE

ANALYTIC HIERARCHY PROCESS



example, only one intermediate level was used (refer to Figure 2). At the top level is the goal: "Select Vendor" for CAD software. Since there is only one intermediate level in this example, the five criteria are recorded at the second level. Three vendors (A, B, and C) submitted proposals, and they are shown at the bottom level.

Stage 3. Determine the Priorities.

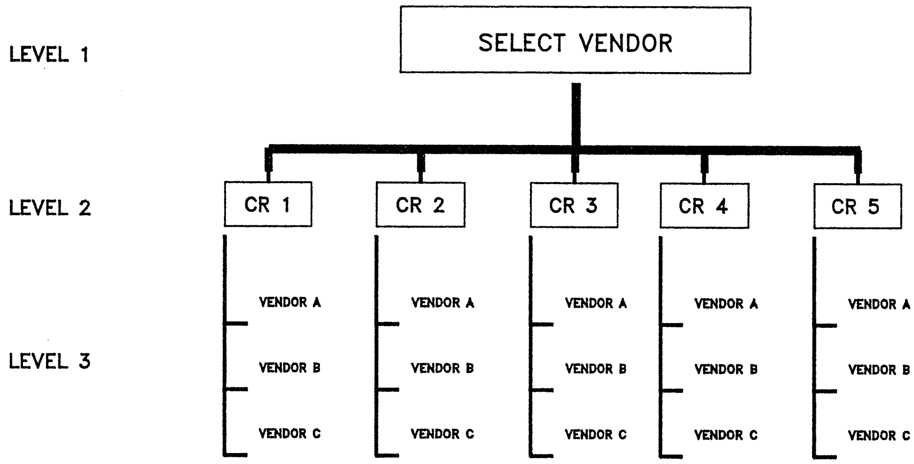
The third step in the AHP involves assessing the relative preference of one vendor over another and assessing the relative importance of the criteria. This assessment procedure is based on pairwise comparisons (criteria and alternatives compared two-at-a-time within the same level). It is suggested that a bottom-up approach be used on the hierarchical levels.

a. Preference Scaling of Projects

For each of the five criteria listed in our example, the three vendors (A, B, and C) were compared two at a time by using a ratio scale (RS) developed by Saaty (Dyer and Forman, 1991). Only one member's preferences are shown in the purchasing example, but each participant would indicate a preference for each vendor in terms of how they perceived that vendor would fulfill the criterion under consideration. The BC member accomplishes this task by comparing the vendors two-at-a-time and by selecting the corresponding intensity of the preference from the ratio scale (RS). [Refer to the Preference Scale shown in Appendix A for a display of the ratio scales.]

To illustrate how the preferences are chosen and recorded refer to Table 1 and the matrix labeled

FIGURE 2
HIERARCHICAL DECISION MODEL FOR VENDOR SELECTION



CR 1 = QUALITY
CR 2 = PRICE
CR 3 = TECHNICAL SERVICE
CR 4 = DELIVERY RELIABILITY
CR 5 = DELIVERY LEAD TIME

"Quality." Then, assume that when vendor A was compared to vendor B, the participant felt that vendor A was "Moderately to strongly preferred" to vendor B with respect to the criterion, Quality. Therefore, referring to the preference scale shown in Appendix A, the corresponding numerical rating for that choice was 4. The number 4 was then recorded in the "Quality" matrix at the intersection of Row A and Column B. Then, vendor A was compared to vendor C. In this case, the decision maker felt vendor A was "Very strongly to extremely preferred" over vendor C. Hence, the numerical rating 8, corresponding to that choice, was recorded in the matrix at the intersection of Row A and Column C. Since there were only three vendors in this example, one other comparison was needed; B was compared to C. Vendor B was considered "Equally to moderately preferred" to C. The numerical rating 2 was recorded in the matrix (Row B, Column C). Since all vendors were equally preferred to themselves, the diagonal of the matrix contains the numerical rating of 1. To complete the remainder of the matrix, the reciprocal of each of the numerical ratings is placed at the appropriate intersection of two vendors. For example, A was preferred 4 to 1 over B; thus, B is recorded as being preferred to A one-fourth of the time (i.e., 1/4 is shown at the intersection of Row B and Column A). Similarly, the intersection of Row C and Column A is the reciprocal of 8 or 1/8. The final intersection of Row C and Column B contains 1/2 which is the reciprocal of 2.

In practice, the participant only compares each vendor to every other vendor once. Computer software or simple formulas in a computer worksheet may be used to calculate the reciprocal values. Also, the vendors could have been compared in a reverse order, for example C to A. The numerical rating for that comparison would be recorded at the intersection of Row C and Column A, and then the reciprocal calculated for Row A, Column C.

Since there are five criteria in this example, each criterion is considered separately, and the vendors are again compared to each other two at a time and recorded in similar matrices. The other four matrices are also shown in Table 1 (Price, Technical Service, Delivery Reliability, and Delivery Lead time).

b. Calculation of Vendor Preferences

The vendor preferences based upon each criterion were determined by converting the numerical ratios into

Table 1
Pairwise Comparison Matrices for Each of the Five Criteria

Quality

Vendor	A	B	C
A	1	4	8
B	1/4	1	2
C	1/8	1/2	1

Price

Vendor	A	B	C
A	1	1/6	1/3
B	6	1	3
C	3	1/3	1

Technical Service

Vendor	A	B	C
A	1	3	6
B	1/3	1	3
C	1/6	1/3	1

Delivery Reliability

Vendor	A	B	C
A	1	4	1/5
B	1/4	1	1/8
C	5	8	1

Delivery Lead Time

Vendor	A	B	C
A	1	1/4	1/8
B	4	1	1/5
C	8	5	1

RATING OF EACH Vendor BY CRITERION

Vendor	Quality	Price	Technical Service	Delivery Reliability	Delivery Lead Time
A	0.72727	0.09601	0.652991	0.206211	0.07042
B	0.18181	0.65299	0.250997	0.07042	0.206211
C	0.09090	0.25099	0.096011	0.723367	0.723367

"weighted preferences." Although there are several methods for determining priorities (weighted preferences) for pairwise comparisons, the AHP incorporates the eigenvector method. The exact mathematical procedure using eigenvalues and eigenvectors is explained by Saaty (1980). For this example, the weighted preferences (ratings of each vendor) are shown in the lower half of Table 1. (For an explanation of how these weighted preferences were calculated, refer to Appendix B.)

c. Importance Scaling of Criteria

This same pairwise process is used to obtain the comparison of the selection criteria at level 2. The participant indicates the relative importance of each criterion in terms of its contribution to the achievement of the overall goal. For this example, 10 pairwise comparisons produced a 5 x 5 pairwise comparison matrix which is shown in Table 2. Again, the participant only creates the initial comparisons between the criteria, two at a time. For example, Quality was deemed to be "Strongly important" in meeting the overall objective when it was compared to Price (Refer to Appendix A for the importance ratio scales). The numerical rating of 5 was recorded at the intersection of Quality (Row 1) and Price (Column 2). After the 10 comparisons were completed and the reciprocals were computed, the priority ratings of the criteria were calculated. For the trade-offs of the criteria for purchasing a CAD system, the selection of the scales was based upon a prior study using the same five criteria (Tullous and Munson, 1991).

d. Calculation of Priorities

The importance of each criterion was determined by converting the numerical ratings into "priorities." The same eigenvalue procedure which was used to determine the weighted preferences was also used to compute the criteria priorities. The criteria priorities (ratings for each criterion) are shown in the lower half of Table 2.

Stage 4. Synthesize the Priorities.

During the fourth step the decision maker integrates all of the paired comparisons to develop the final ratings of the alternatives. Although the computations may be made on a hand-calculator, typically, the comparisons are transferred to a personal computer for analysis. Simple spreadsheet formats may be used, or even decision support system software, such as Expert Choice, (Foreman, Saaty, Selly and Waldron, 1988) may be used. The results of combining the vendor ratings (Table 1)

Table 2
Results of Criteria Comparisons

Pairwise Comparison Matrix -- Five Selection Criteria

Criteria	Quality	Price	Technical Services	Delivery Reliability	Delivery Lead Time
Quality	1	5	4	6	7
Price	1/5	1	1/3	3	2
Technical	1/4	3	1	4	6
Delivery REL.	1/6	1/3	1/4	1	2
Delivery LEAD	1/7	1/2	1/6	1/2	1

Rating for Each Criterion

Quality	0.515
Price	0.118
Technical	0.246
Delivery Reliability	0.070
Delivery Lead Time	0.050

and criteria ratings (Table 2) are shown in Table 3 (Appendix B contains the calculations). For our example, Vendor A has a numeric rating of 0.5657, Vendor B has a numeric rating of 0.2479, and Vendor C has a numeric rating of 0.1874. These ratings are the result of one member's perceptions. The ratings could be combined with other member's ratings to obtain an aggregate rating. Although the technique does not require that the members have consistent perceptions among themselves, it is important that the members show consistency in their own selection process. Thus, AHP provides a mechanism to assist the individual participant in checking their consistency in choosing between the vendors.

Stage 5. Check for Consistency.

In order to check that each participant was consistent when comparing the vendors two-at-a-time, a consistency ratio was calculated. For the set of preferences with respect to the five criteria, a consistency ratio (CR) was calculated for each criterion. The results are shown in Table 4. All of the consistency ratios were less than 0.10, and thus considered satisfactory. An explanation of how the CR was calculated appears in Appendix C.

Table 3
Overall Ratings for Vendors

Vendor A = 0.5647
Vendor B = 0.2479
Vendor C = 0.1874

Implications

The description of analytic hierarchy process (AHP) and the vendor selection example illustrate the basic attributes of AHP that make it a very useful tool for purchasing decision-making. First, the process is easy to understand and implement. Second, the implementation of AHP requires that the BC members understand the needs that the purchase is to satisfy in order to describe the decision problem as a hierarchy. Developing the hierarchy requires that the purchaser state the goal (e.g., which for our example was the selection of CAD system) and identify the key criteria. A second level could have been included which contained objectives (subgoals). That is, the objectives could have set forth the purposes of the purchase for the expectations the purchase was to fulfill. The development of the hierarchy is of value even if the purchaser does not complete all of the steps of the AHP. It forces the members of the buying center to be precise about what criteria are to be considered, and all members of the buying center have the opportunity to introduce those criteria which they consider to be important. This inclusion of all criteria provides for increased understanding of different purchasing viewpoints and stresses the importance of effective communication between members.

Table 4
Consistency Ratios

Quality	0.005
Price	0.016
Technical Service	0.014
Delivery Reliability	0.084
Delivery Lead Time	0.083

Appendix A

Ratio Scales
Pairwise Comparison Scale for the AHP
Preferences for Alternative Projects

Verbal Judgment of Preferences	Numerical Rating
Extremely preferred	9
Very strongly to extremely preferred	8
Very strongly preferred	7
Strongly to very strongly preferred	6
Strongly preferred	5
Moderately to strongly preferred	4
Moderately preferred	3
Equally to moderately preferred	2
Equally preferred	1

Pairwise Comparison Scale for Intensity of Importance of Criteria or Subcriteria

Verbal Judgment of Importance	Intensity of Importance
Extremely important	9
Very important to extremely important	8
Very important	7
Strongly important to very important	6
Strongly important	5
Moderately to strongly important	4
Moderately important	3
Equally to moderately important	2
Equally important	1

While various quantitative elements (e.g., price) are very important factors in purchasing decisions, frequently qualitative criteria are involved. Without structure, the more subjectivity involved in the decision increases the likelihood for more diverse viewpoints. A major strength of AHP is its ability to accommodate the subjective criteria.

For some routine purchasing decisions input from only one member of the buying center may be required. However, the AHP allows for many opinions to be incorporated, and since it does not require general consensus, the selection can represent different views. AHP can combine all of the members' priorities into one overall ranking of the vendors or calculate individual rankings of the alternatives for each member.

Suggestions for Future Research

In this paper, the usefulness of the analytic hierarchy process in purchasing decisions has been illustrated. However, there is a need to examine how such a process might be implemented within a firm. In established organizations there are strong pressures and forces to maintain status quo. It has been shown that the acceptance of new management science techniques is greater when all of the participants are involved with the development of the process. One area of future research will focus on implementation which includes acceptance of the process in purchasing decisions.

Recently, purchasing decisions have been thrust to the forefront in connection with the emphasis that companies have placed on continuous improvement and total quality control issues. A empirical study is currently being designed to compare the AHP method of making purchasing decisions with existing methods in various companies. One of the factors which will be included in the study is the quality of the product purchased.

Other areas for further application and research include: (1) how to refine methods to generate consensus among members of the buying center, (2) how a purchasing data-base could be generated from the use of AHP to assist in future purchases, and (3) the use of AHP in other decision-making situations within an organization.

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Appendix B

The calculations of the priorities (ratings) are based on mathematical operations detailed in Saaty's publications. A brief explanation of how to estimate these ratings is presented in this Appendix.

Calculation of Vendor Ratings:

The pairwise comparison matrix for Quality (as displayed in Table 1) was chosen to illustrate how one set of ratings was estimated in terms of one criterion.

QUALITY

Vendor	A	B	C
A	1	4	8
B	1/4	1	2
C	1/8	1/2	1
Totals	1 3/8	5 1/2	11

Step 1. The calculations were begun by summing each value in each column (1.375, 5.5, 11). Then, each element in a specific column was normalized by dividing that element by the sum of that column, resulting in the following matrix:

Normalized Matrix for Quality

Project	A	B	C	Row Average
A	.7272	.7272	.7272	.7272
B	.1818	.1818	.1818	.1818
C	.0909	.0909	.0909	.0909

Step 2. In the next step, using the normalized matrix, the average of each row was calculated (.7272, .1818, .0909). The averages of the rows provide estimates of the relative priorities of the vendors in terms of the criterion, Quality. The same procedures were made for each of the other four matrices resulting in the priority rankings shown in Table 1.

Calculation of Criteria Ratings:

Similar mathematical operations are performed on the Criteria matrix shown in Table 2. The sum of each column was calculated (1.75952, 9.8333, 5.75, 14.5, and 18). Each element in a column was divided by the respective sum and entered in a normalized matrix. Again, row averages were calculated and the priorities shown at the bottom of Table 2 (.515, .118, .246, .070, and .050).

Calculation of Overall Priorities:

In order to obtain an overall rating of the projects, the ratings for the vendors by criterion are combined with the ratings for the criteria by taking a vendor and multiplying its rating by the criterion rating and summing all the products for that vendor. Placing the ratings in a matrix provides for a quick view of all of the priorities:

	Criteria				
Criteria Ratings	.515	.118	.246	.070	.050
Vendor	Qual	Price	Tech Serv	Del Rel	Del Lead
A (rating)	.727	.096	.653	.206	.070
B (ratings)	.182	.653	.251	.070	.206
C (ratings)	.091	.251	.096	.723	.723

Overall Rating of Project A: 0.727 x .515 + .096 x .118 + .653 x .246 + .206 x .070 + .070 x .050 = .565

Overall Rating of Project B: 0.182 x .515 + .653 x .118 + .251 x .246 + .070 x .070 + .206 x .050 = .248

Overall Rating of Project C: 0.091 x .515 + .251 x .118 + .096 x .246 + .723 x .070 + .723 x .050 = .187

Note: Rounding may cause some priorities to not sum to exactly one; greater precision may be obtained by using spreadsheets or decision support software.

Appendix C

The estimations of the consistency ratios for the purchasing examples are based on mathematical operations detailed in Saaty's publications. A brief explanation of how to estimate consistency ratios is presented in this Appendix. A consistency ratio (CR) may be calculated for each of the matrices in Table 1 (Quality, Price, Technical Service, Delivery Reliability and Delivery Lead Time).

Calculation of Consistency Ratios

For illustrating how one consistency ratio was estimated for one criterion in terms of preferences of vendors, the pairwise comparison matrix for Quality (as displayed in Table 1) was chosen:

QUALITY

Vendor	A	B	C
A	1	4	8
B	1/4	1	2
C	1/8	1/2	1
Totals	1 3/8	5 1/2	11

The relative priorities (ratings) of the vendors was also given in the lower portion of Table 1: A = 0.72727; B = 0.18181, and C = 0.090909. To check for consistency of the participant's judgments in comparing vendors when considering the criterion, Quality, four steps are needed:

Step 1: Multiply the relative ratings by the values in each of the corresponding columns. For example, multiply values in column A by 0.72727, the values in column B by 0.18181, and the values in column C by 0.090909. Sum the values across the rows to obtain the weighted sum vector (WSV).

$$.7272 \begin{matrix} 1 \\ 1/4 \\ 1/8 \end{matrix} + .1818 \begin{matrix} 4 \\ 1 \\ 1/2 \end{matrix} + .0909 \begin{matrix} 8 \\ 2 \\ 1 \end{matrix} = \begin{matrix} \text{WSV} \\ 2.181 \\ 0.545 \\ 0.272 \end{matrix}$$

Step 2: Divide the weighted sums in the vector obtained in Step 1 by the corresponding ratings and find the average.

2.181/.7272 = 2.999; 0.545/.1818 = 2.997; 0.272/.09 = 3.022

AVG = (2.999 + 2.997 + 3.022) / 3 = 3.006

Step 3: Compute the consistency index (CI) which is defined as follows:

$$CI = \frac{AVG - n}{n - 1}$$ where n = number of items being compared

$$CI = \frac{3.006 - 3}{3 - 1} = 0.003$$

Step 4: Compute the estimated consistency ratio (CR) which is defined as follows:

CR = CI/RI where RI is the consistency index of a randomly generated pairwise comparison matrix. For n = 3, the RI is 0.58.

CR = .003/.58 = .005

A consistency ratio of 0.10 or less indicates the judgments are consistent.

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