SOFTWARE SELECTION

The evolution of microcomputer hardware and the proliferation of business and managerial applications of computing have led to changes in the characteristics, uses, sources, evaluation, and selection of software. With the acceptance of microcomputers and the emergence of end-user computing, more and more software is mass produced and distributed as "packages." This has created a difficult problem of software evaluation and choice for many users. The problem is made difficult by quantitative and qualitative attributes in the evaluation and selection process.

Qualitative attributes are those attributes which are identified but cannot be quantified in meaningful (numerical) terms. Qualitative attributes are important elements in a selection decision, but the lack of a quantified value for them restricts their inclusion in many decision models.

Although a number of decision models and techniques to select software packages such as

1. a linear weighted attribute model (1,2)
2. a linear assignment model (3,4)
3. maximax (5)
4. elimination by aspects (6)
5. lexicographic ordering (7)

have been proposed, these models and techniques either have not incorporated qualitative attributes or have not considered multiple criteria in the decision process.

This paper applies the analytical hierarchy process (AHP) method as a multicriteria decision support tool for evaluating and selecting microcomputer software packages.

SOFTWARE SELECTION PROCESS

One of the decisions that information system managers frequently face is whether to develop or buy software. In the past few years, this decision has become even more complex and challenging, because today there are so many powerful and versatile off-the-shelf software programs available for a wide variety of tasks. Software purchase has become an attractive alternative to in-house development. It provides economies of scale while altering the risk profile of the implementation project. Software selection is a critical decision with serious financial implications and affects the productivity of the organization.

THE ANALYTIC HIERARCHY PROCESS

The analytic hierarchy process (AHP), developed by Saaty (8–10), makes a significant contribution to understanding and explaining how decision makers exercise judgment when confronted with complex, nonprogrammed decisions. By allowing decision makers to model a complex problem in a hierarchical structure showing the relationships of goals, criteria (attributes), and alternatives, it allows for the application of experience, insight, and intuition logically and thoroughly.

The AHP methodology is useful for systematically evaluating (often conflicting) qualitative criteria. Similar to other multiattribute decision models, the AHP attempts to resolve conflicts and analyze judgments through a process of determining the relative importance of a set of attributes or criteria. The AHP enables a decision maker to develop the tradeoff among multiple criteria implicitly in the course of structuring and analyzing a series of pairwise judgmental comparison matrixes. The major difference between the AHP and other multiattribute decision models (i.e., utility theory) is that the AHP enables the systematic structuring of any complex multidimensional problem.

The attributes of the AHP satisfy the requirements of a good software selection methodology. It allows specifying factors in a multicriteria setting, provides the ability to express the relative importance of the multiple criteria being considered, and uses pairwise comparisons to extract information.

The AHP has been used extensively in practice, including some areas similar to integrated software selection. Zahedi developed a decision mechanism for microcomputer database software selection, using the AHP to quantify the evaluation (11). Seidmann and Arbel used the AHP in selecting among four alternatives for a microcomputer-based accounting information system (12). The objective was to select the best microcomputer for accounting information management in the firm. They also used the AHP in selecting a microcomputer for process control and data acquisition (13). Johnson and Hihn identified the usefulness of the AHP in selecting among potential projects in the field of energy storage (14). With the introduction of its PC implementation, Expert Choice (EC), the number and diversity of applications has grown rapidly (15). IBM used Expert Choice on its Application Systems/400 (AS/400) Project in Rochester, MN to help win the Malcolm Baldrige Quality Award. General Motors' Advanced Engineering Staff used EC to help future car designers evaluate design alternatives, perform risk management, and arrive at the best and most cost-effective automobile designs. Xerox Corporate Research and Technology and the Technology Management groups used EC for R&D decisions on portfolio management, technology implementation, and engineering design selection. EC is also used to help make marketing decisions regarding market matching and customer requirement structuring (16). A comprehensive list of major application of AHP is in *The Hierarchon: A Dictionary of Hierarchies* (17).

STEPS OF THE ANALYTIC HIERARCHY PROCESS

Using the AHP to solve a decision problem involves four steps.

Step 1: Setting Up the Decision Hierarchy

One of the distinguishing features of this approach is the use of hierarchical structure to represent the decision problem, independent of problem complexity or the number of criteria. Hierarchical decomposition is one of the most commonly used methods by which decision makers factor complex problems into more manageable subproblems. Humans have the ability to perceive things and ideas, to identify them, and to communicate what they observe. For detailed knowledge our minds structure complex reality into its constituent parts, and these in turn into their parts, and so on hierarchically. By breaking down reality into homogeneous clusters and subdividing these clusters into smaller ones, we can integrate large amounts of

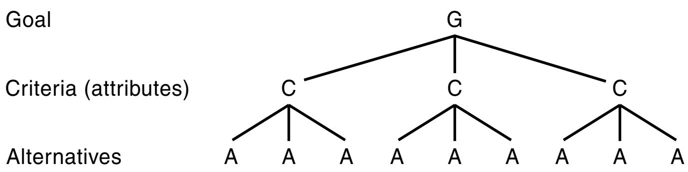

Figure 1. Decision alternatives for selection choices.

information into the structure of a problem and form a more complete picture of the whole system. Generally, the hierarchy has at least three levels. At the top of the hierarchy lies the goal of the decision problem. The lower levels of the hierarchy contain attributes which contribute to the quality of the decision. The last level of the hierarchy contains decision alternatives for selection choices (Fig. 1).

Step 2: Collecting Input Data by Pairwise Comparisons of Decision Elements

The AHP makes it possible to rank alternative courses of action based on the decision maker's judgments on intangible qualitative criteria alongside tangible quantitative criteria. The problem hierarchy lends itself to an analysis based on the impact of a given level on the next higher level. The process begins by determining the relative importance of the criteria in meeting the goals. Next, the focus shifts to measuring the extent to which the alternatives achieve each of the criteria.

Managerial judgments are used to drive the AHP methodology. These judgments are expressed in terms of pairwise comparisons (as contrasted with simultaneous comparisons) of attributes on a given level of the hierarchy with respect to their impact on the next higher level. Pairwise comparisons express the relative importance of one attribute versus another in meeting a goal or a criterion. Each of the pairwise comparisons represents an estimate of the ratio of the weights of the two criteria being compared.

The use of pairwise comparisons to collect data from the decision maker offers some advantages. It allows the decision maker to focus on the comparison of just two attributes, making the observation as free as possible from extraneous influences. Additionally, pairwise comparisons generate meaningful information about the decision problem, improve information about the decision problem, and improve consistency (compared to simultaneous comparison) in the decision making process.

Although there are many scales for quantifying managerial judgments, the numeric scale given in Table 1 is the standard for the AHP analysis. For example if a decision maker believes that attribute A is moderately more important than attribute B, then this judgment is represented by a 3. Judgments are required for all the criterion comparisons and for all the alternative comparisons for each criterion.

The pairwise comparison for each component of the problem is represented by comparison scales (Table 1). The rationale for a 1–9 scale is based on psychological experiments (18). The matrix is reciprocal in nature, reducing the number of needed comparisons by half. The rationale for reciprocity is intuitive. Once a response is gathered for a particular comparison, the exact "opposite" response should be true for the same comparison when reversing the order.

Step 3: Estimating the Relative Weights of Decision Attributes

The third step is to determine the relative importance of the alternatives with respect to each criterion(attribute). The pairwise comparison matrix for a given criterion is used to rank (i.e., establish the relative importance of) the alternatives. This is accomplished by the scaling function previously identified. By applying established attribute weights, the resultant normalized values for the individual alternatives are computed. The process is repeated for every criterion. Each results in a distinct ranking of alternatives.

Step 4: Computing the Rating of Alternatives

Finally, the results of the two analyses are synthesized to compute the ratings of the alternatives in meeting the goal. After all alternative comparisons are made for each criterion, their relative importance are then elicited from the decision maker by the same pairwise comparison process used in evaluating the alternatives. When comparing the importance of the individual criteria, the typical question asked of the decision maker is: "In comparing the benefits obtained by attribute A and the benefits obtained by attribute B, which is more important to the entire organization?" As before, all pos-

Table 1. Pairwise Comparison Scale

Intensity of Importance[a]	Definition	Explanation
1	Equal importance	Two attributes contribute **equally** to the objective
3	Moderate importance of one over another	Experience and judgment **slightly** favor one attribute
5	Essential or strong importance	Experience and judgment **strongly** favor one attribute
7	Demonstrated importance	An attribute is **strongly** favored and its dominance demonstrated in practice
9	Absolute importance	The evidence favoring one attribute over another is of the **highest** order
2,4,6,8	Intermediate values between the two adjacent judgments	When compromise is needed

[a] Reciprocals of the above values: If attribute ***i*** has one of the nonzero numbers assigned to it when compared to attribute ***j***, then ***j*** has the reciprocal value when compared with ***i***.

Table 2. Criteria Comparison Matrix

	TR	FR	EofU	VS	TT	Pr
TR	1	1	1	5	9	1
FR	1	1	2	9	9	2
EofU	1	1/2	1	5	9	1
VS	1/5	1/9	1/5	1	2	1/5
TT	1/9	1/9	1/9	1/2	1	1/8
Pr	1	1/2	1	5	8	1

sible pairwise comparisons are made, and the responses are placed numerically in another comparison matrix, using the same 1–9 scale identified previously. Once comparison matrixes are constructed for alternatives and criteria comparisons, the final step is to determine the overall ranking of the alternatives.

Establishing the overall ranking of the alternatives involves three steps. The first is to determine the relative importance of the criteria using the comparison matrix constructed by the decision maker. The largest eigenvalue and the corresponding principal eigenvector of this matrix are calculated. (The exact rankings, collectively known as a vector in mathematical language, are derived by raising the comparison matrix to large powers by, for example, squaring it, then squaring that result, and so on. The rows of the resulting matrix are added and then normalized. The computer is instructed to quit when the normalized vector from the previous power is within a prescribed decimal accuracy from the next power. This process yields what is known in mathematics as the principal eigenvector of the matrix.) The principal eigenvector is normalized, so that its entries sum to one. The normalized eigenvector represents the relative importance of the criteria.

Finally, the relative importance of the alternatives for each criterion and the relative importance of the criteria themselves are used to determine the overall ranking of the alternatives. Assume that the relative importance of m alternatives have to be established using n criteria. The overall relative importance of alternative j (A_j) is determined from the expression.

$$A_j = \sum_{i=1}^{n} C_i P_{ij}$$

where C_i = relative importance of criterion i and P_{ij} = relative importance of alternative j with respect to criterion i.

The larger the value of A_j, the higher the relative importance of alternative j. Thus, the composite values of A_j represent the relative ranking of the alternatives under evaluation.

A HYPOTHETICAL EXAMPLE

A hypothetical example is presented here to illustrate how the AHP is used. This example consists of a selection problem where there are three competing software packages (S1, S2, and S3) and their ranking is based on six criteria deemed important for a particular organization. The criteria are (1) technical requirements (TR), (2) functional requirements (FR), (3) ease of use (EofU), (4) vendor support (VS), (5) training time (TT), and (6) price.

Table 2 shows the comparison matrix which indicates the results when evaluating the relative importance of the criteria in a pairwise fashion. Table 3 shows the comparison matrixes indicating the pairwise evaluation of the way software packages address each criterion.

Table 3. Software Comparison Matrixes

	S1	S2	S3		S1	S2	S3
	Technical Requirements				*Vendor Support*		
S1	1	7	5	S1	1	1/2	1
S2	1/7	1	3	S2	2	1	3
S3	1/5	1/3	1	S3	1	1/3	1
	Functional Requirements				*Training Time*		
S1	1	1/2	3	S1	1	1	1
S2	2	1	6	S2	1	1	1
S3	1/3	1/6	1	S3	1	1	1
	Ease of Use				*Price*		
S1	1	1/3	1	S1	1	1/3	1
S2	3	1	5	S2	3	1	3
S3	1	1/5	1	S3	1	1/3	1

Table 4 provides the relative importance of the software packages by criterion type. For example, using the software comparison matrix for the TR criterion (C1), the normalized eigenvector calculated is shown in the TR column. Larger values of the eigenvector indicate greater importance of software packages with respect to the criterion. Thus, S2 best addresses the TR criterion, followed in decreasing order by S3 and S1. This process of calculating the normalized eigenvector is repeated using the software comparison matrixes for functional requirements, ease of use, vendor support, training time, and price. The results of these calculations are provided under their respective columns. The results indicate that S2 is the best software alternative for the FR criterion, S2 is the best software for the ease of use criterion, and S2 is the best alternative for price.

The normalized eigenvector of the criteria comparison matrix is also shown in Table 4. It indicates the relative importance of the criteria based on the decision maker data. The computational results yield the following: the functional requirements criterion is the most important, followed in importance by technical requirements, ease of use, price, vendor support, and training time. Table 5 illustrates the final overall ranking of the three software alternatives. From this, the ranking order is (from best to worst) S2, S1, and S3.

Table 4. Relative Importance (Normalized Eigenvectors)

	TR	FR	EofU	VS	TT	Pr
S1	0.072	0.300	0.185	0.240	0.333	0.200
S2	0.649	0.600	0.659	0.550	0.333	0.600
S3	0.279	0.100	0.156	0.210	0.333	0.200
	(C1)	(C2)	(C3)	(C4)	(C5)	(C6)
Criteria relative priority:	0.225	0.316	0.199	0.041	0.025	0.194

Table 5. Composite Ranking

S1: 0.225 * (0.072) + 0.316 * (0.300) + 0.199 * (0.185) + 0.041 * (0.240) + 0.025* (0.333) + 0.194 * (0.200) = 0.205
S2: 0.225 * (0.649) + 0.316 * (0.600) + 0.199 * (0.659) + 0.041 * (0.550) + 0.025* (0.333) + 0.194 * (0.600) = 0.614
S3: 0.225 * (0.279) + 0.316 * (0.100) + 0.199 * (0.156) + 0.041 * (0.210) + 0.025* (0.333) + 0.194 * (0.200) = 0.181

CONCLUSIONS

This article discusses an overall process for evaluating and selecting a software package by the AHP methodology. This decision support tool allows a decision maker to incorporate qualitative and quantitative criteria in the decision process. Technical requirements, functional requirements, ease of use, vendor support, training time, and price are considered the decision criteria for selecting one of the three software packages under evaluation. The application described in this paper was carried out with the aid of an interactive computer program (Expert Choice) to compute the priority vectors. Major conclusions from similar applications of the model find that is valid, flexible, easy to apply, and does not overlook any significant factor.

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