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A Decision Support System using Multiattribute Utility Model

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Abstract

When people choose one way of action from various alternatives, they make value judgement. Due to limited capacity of human information processing, however, a decision maker cannot reflect his true subjective utility in evaluating alternatives especially for a problem which has multiattribute. The analytic hierachy model is a tool which converts scores derived from pairwise comparison with respect to each attribute to overall scores of the alternatives. Then the overall scores are utilized to choose an alternative. Therefore this model can be used to support people's value judgement.

1. The role of decision support system

Keen and Scott Morton (1978) suggested that decision support implies the use of computers to (1) assist managers in their decison processes in semistructured tasks, (2) support, rather than replace, managerial judgement, (3) improve the effectiveness of decision making rather than its efficiency. A decision support system complements limitations of human ability in decison making on complex problems which humans face every day.

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It supports to solve problems that are relatively unstructured. "The various definitions that have been suggested for decison support system agree that the system must aid a decison maker in solving unprogrammed, unstructured problems" (Bonczek, Holsapple and Whinston, 1979).

Contemporary choice making issues in the public and private sector are complex, contain much uncertainty, and requires inputs from many sections for full understanding and resolution. In making choice, people use two kind of judgements. First, people make value judgements by which they express preference, for example : for one job over another, for one school compared to another, etc. Second, people make predictions which reflect what they expect to happen, for example : how stock price will behave in the near future, etc. These judgements involve the integration of a great deal of informations. Computer based decision support systems can reduce the dcision makers' burden of integrating information.

Bonczek, Holsapple and whinston (1979) suggested that a main feature distinguishing decision support system (DSS) from management information system〈MIS〉 is their computational modeling capabilities. DSS usually use models to give result of information to decision makers who have limited information processing capability. These models are based on axioms and rules of mathematics. Therefore, these models are completely rational and consistent. But models cannot reflect all the complexities of problems in the real world. Models are bounded by assumptions and quantifiable factors which are needed to simplify complex problems. Thus, what the models used in DSS to solve complex real world problems can do is just complimenting human decision making process.

Carlson (1983) pointed out two categories of potential benefits of DSS : displaced cost and added value. Displaced cost results from reduced cost for data gathering, computation and data presentation in support of decision making. Added value results from investigating more alternatives, doing more sophisticated analyses of alternatives, using better methods of comparing alternatives, making quicker decisions, etc.

2. Limitations of human ability in decision making

People make value judgements in decision making and then choose one way of action which gives greatest value to them, among various alternatives.

Hogarth (1980) suggested that choice reflects both evaluative and predictive judgements, and the quality of choice depends upon the extent to which (1) evaluative judgements really translate true preferences, and (2) predictive judgements are accurate. These judgements are made on the basis of information which has been processed and transformed by the human mind. Various studies in various disciplines lead to conclusion that people have limited information processing capacity.

Hogarth (1980) also suggested that there are four major consequences of limited human information processing capacity. First, perception of information is not comprehensive but selective. Therefore anticipation plays a large part in what we actually see. Second, since people cannot simultaneously integrate a great deal of information and processing is mainly done in a sequential manner. Therefore the actual sequence in which information is processed may bias a person's judgement. Third, people use fairly simple procedures in order to reduce mental effort. Fourth, due to limited memory capacity, people memorize events selectively and reconstruct events in their memory. Therefore memory also may bias a person's judgement.

people needed to integrate a great deal of information to make decision. But due to limitations of information processing capacity, people frequently make poor decision.

> The capacity of the human mind for formulating and solving complex problems is very small compared with size of the problems whose solution is required for objectively rational behavior in the real world or even for a reasonable approximation to such objective rationality. (Simon, 1957, p. 198)

With the observation, Simon asserted the bounded rationality of human decision making. Due to this bounded rationality, decision makers do not really attempt to obtain an optimum or best solution to a problm. Instead they use simplistic decision strategies, relatively simple procedures or rules of thumb that do not require information processing capabilities beyond those of the unaided human information processing system. Thus choice is always exercised with respect to a omitted, approximated, simplified model of the real situation. This simplified model of decision situation in human mind may not contain an element of information whose inclusion would increase the chances of making a higher quality decision.

Problems in the real world include a great deal of uncertainties. Allias (1953), and Slovic and Tversky (1974) showed inconsistencies of people in gambling situation which include uncertainty. These evidence indicates that the structure of tasks causes some inconsistencies in expression of preference in condition of choice under uncertainty. "One possible explanation is that in making choices which involve conflicting dimensions, people selectively attend to one of dimensions" (Hogarth, 1980, p71). Most of decision problems include multiple objectives some of which conflict with others. In this situation, people may exhibit inconsistencies in making decision.

Tversky (1969) observed discrepancy between rational theory and actual behavior as the decision making task increases in complexity. In particular : (1) intuitive probabilistic inferences deviate drastically from those probability theory, (2) decision makers ignore many relevant variables in order to simplify their problem to a scale consistent with the "computational capacities" of the human intellect, and (3) decision makers rely on heuristic decision rules which systematically violate the expected utility principles.

3. Decision making with multiple-objectives and multiattribute utility model

Decision makers are frequently confronted with conflicting objectives in a problem. For example, a businessman may be concerned not only with short-term profits, but also with market share and development of the personel in operating his firm. Actually most of the real world problem includes multi-objectives and multiattributes which contributes to overall objective. When a decision maker faces this situation, he should make trade-offs among conflicting objectives and evaluate the degree of contribution of attributes.

Multiattribute utility procedures can provide some comforts and assistance to the person who faces with such conflict. They are based on axiomatic theories that prescribe the conditions under which an object's value can be expressed as an algebraic combination of its separate components (Krantz et al., 1971).

When a decision maker evaluates decision alternatives, he evaluates alternatives based on his subjective utilities of consequent effects of each alternatives. Due to limited ability of humans and the nature of multidimensionality of decision problems, he could not reflect his true subjective utilities in evaluating alternatives. Multiattribute utility model aids decision makers to reflect their true subjective utility in evaluating alternatives.

Fischer (1979) summarized development in multiattribute utility model (MAU) and classified into three models: (1) additive utility model, (2) quasi-additive utility model and (3) multi-linear model. Fischer (1979) reports that relatively simple MAU models will provide an excellent approximation to human preferences across a broad range of decision settings refer to various psychological researches. Among these three MAU models additive utility models would be the simplest one.

Additive MAU model can expressed as follows.

$$U = \sum_{i=1}^{i=N} w_i a_i$$

where U ; overall utility

N ; number of attributes

W_i ; importance weight of i-th attribute

a_i ; subjective utility score which decision maker assigned to the i-th attribute

Then the alternative which obtain highest U score is the best to the decision maker.

Park (1978) reported that a seven-point scale additive MAU model predicts consumers' product choice fairly in selection of automobiles. Miller (1956) concluded in his studies of human memory and judgement processes that people are capable of actively coding and manipulating at most eight to ten "chunks" of conceptual information at any given time. A MAU model can incorporate large numbers of attributes by decomposing assessment. Thus it can extend human ability of evaluation. In fact, Anderson (1974), and Slovic and

Lichtenstein (1971), after reviewing the extensive literature on human prediction, evaluation, and choice, conclude that simple additive or multi-linear models typically explain virtually all of systematic variance in human judgement process. Fischer (1979) also concluded that "decomposed MAU modeling techniques make possible the formal analysis of decision problems characterized by large numbers of possible outcomes each of which is described by multipe relevant attributes."

As discussed, the human mind is incapable of integrating large amounts of information. Accordingly, direct evaluation of alternatives are not feasible when a large number of value considerations is viewed as relevant. Therefore MAU models would be a good aid for alternative evaluation in this situation.

4. Multiattribute assessment by the analytic hierachy process

Given limited ability of humans in decision making, differences among objects would be easily captured by pairwise comparison of objects. Non-metric multidimensional scaling which is used broadly in various disciplines is based on the assumption that human judgement between two objects at a time is superior to simultaneous judgement among all objects at once.

Saaty (1980) proposed the analytic hierachy process to assess multiattribute utility. This process produces importance weights of attributes to next higher level attributes. A brief review of this process is as follows. (Saaty, 1980)

4.1 Hierachies

MAU models decompose overall objective to many attributes which contribute to achive this overall objective. And this decomposition can be arranged hierachically. For example, overall welfare of a nation can be decomposed hierachically as Figure 1.

Then we can determine importance weights of each components in the third level hierachy to each component in second level hierachy systematically. With these weights, we can evaluate alternative programs which contributes to overall welfare of the nation.

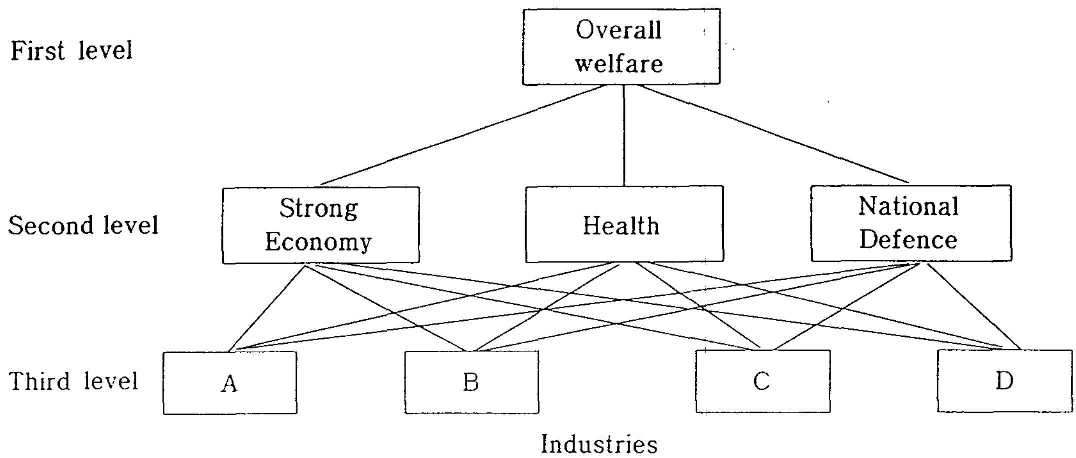


Figure 1

The analytic hierachy process is a mathematical method of obtaining these weights by using the characteristics of eigen vector of a matrix.

4.2 Procedure

i) Formulation of value matrix

If we identify attributes of a certain hierachy level, we can form a matrix by pairwise comparison. In the Figure 1 above, for example, let's assume we intend to obtain relative importance of industries (A, B, C, D) to overall welfare of the nation. First, we can assign value of relative importance of industries with respect to a second level attribute (for example strong economy) by pairwise comparison using 1 to 9 scale with the following rule.

Second level attribute : Strong economy

Industries	A	B	C	D
A				
B				
C				
D				

Given attributes or alternatives A and B; if

A and B are equally important, insert 1

A is weakly more important than B, insert 3

A is strongly more important than B, insert 5

A is demonstrably or very strongly more important than B, insert 7

A is absolutely more important than B, insert 9

in the cross section of A row B column.

With this rule, the main diagonal of the matrix must consist of 1's. And values in the lower triangle of the matrix are reciprocals of upper triangle of the matrix. Here 1 to 9 is assummed as continuum and one can assign any values between 1 and 9. With successive pairwise comparison, we can form a matrix as follows.

Second level attribute : Strong economy

Industries	A	B	C	D
A	1	5	6	7
B	1/5	1	4	6
C	1/6	1/4	1	3
D	1/7	1/6	1/3	1

In this value matrix, the decision maker judged that industry A is strongly more important than industry B (score 5) with respect to the attribute strong economy. Similarly other numbers mean relative importance of industries placed on the left column compare to industries placed on the upper row with respect to the given attribute.

By the same manner, we can make one value matrix for each second level atrribute and a value matrix representing relative importance of second level attributes with respecct to the first level objective.

ii) Obtain eigen values and eigen vectors

After construction of value matrices, we can obtain eigen values and eigen vectors of each matrix in the computer. Then an eigen vector associated with the largest eigen value is used to determine weights of alternatives or attributes with respect to next higher level attribute. Actual weight number of an attribute is corresponding element of normalized form of this eigen vector. After obtained weights of all matrices, we can derive weights (relative importance) of the lowest level alternatives with respect to the highest level objective by wrapping up from lower level to higher level. The largest eigen value is also used to measure consistency of corresponding value matrix.

iii) Consistency

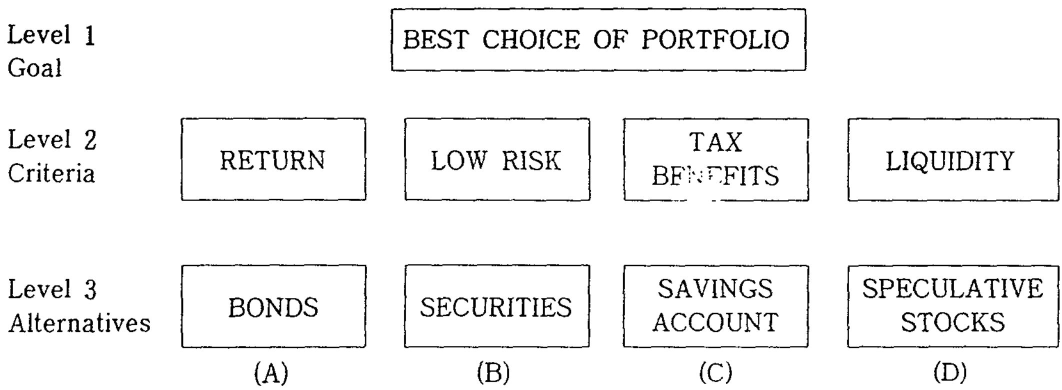
If the judgements are perfectly consistent, the largest eigen value (λ_{max}) equals to the sum of main diagonal elements of the matrix (n) and the rest of the eigen values are zero. Therefore the analytic hierachy process uses the term $(\lambda_{max}-n)/n$ as the consistency index. Saaty suggests that if this index is less than or equal to 0. 1, the judgements are acceptable as consistent. If the index is greater than 0. 1, we can adjust judgements to meet consistency requirement. It can be done by adjusting the element of the matrix which has the largest value of term $a_{ij}-w_i/w_j$; where a_{ij} is the value of the element at i th row and j th column, and w_i and w_j are weights of attributes i and j.

5. Application to a decision spport system

A multiattribute model with the analytic hierachy process would be useful for decision support system to support individual decision maker who has to choose an alternative among many alternatives which have multiattribute characteristics. This model can provide interaction between computer and the decision maker to adjust his consistency of judgements and to perform sensitivity analysis to see how the ranking of alternatives changes as his judgement scores change. With this sensitivity analysis he can understand what attributes are critical for determining the ranking and trade-off ratios among alternatives.

5.1 Inputs

i) A decision maker decomposes problems into hierachical structure of attributes. For example, formulating an investment portfolio case can be decomposed as follows (Saaty, 1987).



In this example, a decision maker inputs a value matrix of criteria (level 2) with respect to goal (level 1).

ii) Then he inputs a value matrix of alternatives (level 3) with respect to each criterion (level 2) by the same manner with which he formed the value matrix of criteria.

Criterion : RETURN

Alternatives	A	B	C	D
A	1	1/3	1/5	1/5
B	3	1	1/2	1/6
C	5	2	1	1/3
D	5	6	3	1

5.2 Outputs

With the inputs, the model gives priority vector, which represents importance weights for the criteria and a consistent index for each input matrix. It also gives importance weight with respect to objective (level 1) for each alternative and overall ranking of alternatives in current judgement. This procedure can be programed in a computer and incorporate the program in a decision support system. In the portfolio example, the importance weights would be used as proportions of investment items included in the portfolio.

5.3 Interaction

The decision maker can perform sensitivity analysis with the model. Then he can obtain border line value of his judgement scores for current ranking of alternatives for each attribute. Accordingly, he can get firm knowledge about the problem with which he makes decision. In other words he can make better decision with this system.

6. Conclusion

Humans show limited capacity in information handling and bounded rationality when they face complex real world problems. Consequently, humans make biases in information processing and frequently make poor decision. Due to development of computers, this limited ability of humans can be expanded with proper aid using computers. Computers have rapid computational capability and capacity of handlng enormous amount of information without any bias or distortion.

Final decision is made by humans who take action for implementing the decision. Therefore computers cannot substitute for decision makers. Accordingly, the role of a decision support system is to support and complements the limited ability of humans in decision making.

Past researches reported that simple algebraic multiattribute models have been able to provide excellent approximations to human preferences in virtually every context studied in psychology. The analytic hierachy process can provide systematic utility assessment for multiattribute models. Therefore multiattribute model based on the analytic hierachy process which is modeled in the computer can give good support for a decision maker.

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