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A DECISION MODEL FRAMEWORK FOR A CLASS OF SOCIETAL PROBLEMS

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ABSTRACT

A recurring problem in public agencies and institutions is the need to select a limited number of alternatives from many submitted for consideration. This is true in funding for research, in considering resource allocation for social needs, or in selecting candidates for school admission. The common features of this class of societal problems provide a unifying framework for generating a structural decision model to guide the process of problem representation and serve as a rational basis for good solutions. This paper provides a framework for such a structural model that includes six stages: modeling the decision process, information gathering, screening alternatives, judging feasible alternatives, announcing the decision, and evaluating the decision process.

INTRODUCTION

A recurring problem in public agencies and institutions is the need to select a limited number of alternatives from a large number submitted for consideration. This is true in funding for research, in considering resource allocation for social needs, or in selecting candidates for school admission. In all cases there are common features that can provide a unifying framework for generating a structural decision model to guide the process of problem representation. The common features are: (1) limited resources, (2) a desire to select alternatives with the highest potential of contributing to the realization of the organization's multiple objectives, (3) the objectives may be expressed in terms of important attributes of the alternatives, (4) a set of alternatives is to be considered, and (5) a need to stipulate a criterion for making a selection of alternatives that contributes to the achievement of the organization's objectives. The following three examples belong to the class of societal problems treated here.

Development of California Coastline

The California Coastal Commission was created by the California state voters to regulate the development of the ocean coastline in California. The Commission receives numerous building permit requests. Many important attributes of the requests are identified, such as height of the building, size of the development, distance from tide line, density, unit rental, and esthetics of the development. Edwards (1977) describes the decision process of the Commission.

Funding for Educational Programs

Suppose a government agency is considering three possible programs for student financial aid. It might evaluate the programs on the basis of impact on the broad attributes of student persistence, student choice, student access, and the impact of the Federal programs on State student aid policy.

School Admissions Procedures

Applicants to postsecondary schools submit information about themselves to admissions committees. The committee must develop a process for judging among many applicants. Some attributes for judgement may be Grade Point Average (G.P.A.), Recommendation quality, and standardized test scores.

FRAMEWORK

An organization faced with the task of repeatedly evaluating alternatives will gain much by establishing a formal judgement procedure. The scope of the decisions may dictate the effort to be devoted to the task. If the alternatives are allocations of one hundred dollar emergency loans to needy employees, a simple system for assessing the employee's need may suffice. When the alternatives are sites for a nuclear power plant, a more in-depth procedure may be necessary.

However, all procedures will have common elements. These common elements are represented in Figure 1 in six stages. The first stage is the modeling stage, in which specifications of the steps to be taken in the succeeding stages are made and attributes for evaluating the alternatives are identified. There is then a stage in which information is gathered about the available alternatives and about the environment. In the screening stage, the alternatives are screened by checking if they satisfy threshold values for the attributes. The number of attributes relevant to the problem is reduced by considering how strong each attribute is as a discriminator among the alternatives. Alternate processes for judging among feasible alternatives are described. In the last two stages, the decision is announced and the entire process is evaluated.

The activities at each stage tie in with the other stages and the process does not strictly flow from Stage One to Stage Six sequentially. For example, during the information gathering stage, new alternatives may arise and alter the procedure

STAGE ONE:	MODEL THE DECISION PROCESS AND IDENTIFY IMPORTANT ATTRIBUTES
STAGE TWO:	GATHER INFORMATION
STAGE THREE:	SCREEN ALTERNATIVES
STAGE FOUR:	JUDGE FEASIBLE ALTERNATIVES
STAGE FIVE:	ANNOUNCE DECISION
STAGE SIX:	EVALUATE THE DECISION PROCESS

Figure 1. Stages in the Decision Process

which was established in the modeling stage. In this case, a return to the modeling stage may prove fruitful.

DESCRIPTION OF MODEL STAGES

Stage One: Model the Decision Process

At this stage, a model for the complete decision process is constructed. An outline of the specific forms of Stages Two through Six is included in the model. First, the current decision process is examined. Unless the current decision situation is one which has never before been encountered by the organization, there will be some existing procedure. It may be possible to revise the current process, or even keep it intact. Possibly, a totally new process will be developed at this stage.

The alternatives are assumed to be currently available to the organization; the key task is to choose among them. If more than one alternative is to be accepted, then a portfolio-balancing scheme may be employed to achieve a desired balance. If a list of possible attributes for evaluating the alternatives exists, then the list should be examined and updated. If no list exists, it should be created. One method for developing such a list is to employ a cross-impact matrix. For example, the organization's higher level objectives may have already been specified, perhaps in a long-range plan. Then, a cross-impact matrix can be used to represent how lower level attributes contribute to the long range organization objectives. The rows of the matrix correspond to possible attributes of the alternatives and the columns to the organization objectives. The entry in the ith row and jth column of the matrix represents how important attribute i is in meeting objective j. Attributes that contribute minimally to the organization objectives may be eliminated from further consideration.

Choice of decision process The development of the decision process should meet situation-specific criteria. For example,

The process may be simple, consistent with the organizational communication structure, disclosable, economical in the use of resources such as time and money, and harmonious [Dyer and Miles (1976)]. The process may evolve over time, possibly through formalization of current ad hoc procedures.

Identification of decision maker Ther may be many committees or organizations with joint responsibility for the decision. In a case of multiple decision makers, the decision process should explicitly identify the tasks of each. If the process does not follow the existing lines of communication and responsibility in the organization structure, new interaction patterns must be developed. It is important to consider the role of the decision maker. Administrators should not be alienated by being deprived of a discretionary role. Some decision makers may prefer to be given the rankings of the alternatives, while others may prefer to be given only information on the attributes of each alternative, so they may make their own qualitative judgements.

Forms of presenting processed information A popular form for presentation of information to the final decision maker is an overall score for each alternative based on its performance on the determinant attributes. The scores may be computed by a weighted average of the performance of a specific alternative on the determinant attributes, for example.

Alternatively, information about all alternatives may be presented to the decision maker who then makes a qualitative judgement, possibly by ordinally ranking alternatives. If there are many decision makers, a vote may be taken.

It is important in this stage to decide whether elements of uncertainty should be included in the decision model. One purpose of the decision process model is to identify a manageable number of key elements for evaluating alternatives. If uncertainty is not a major factor, then the model can be portrayed as being a situation under certainty, otherwise it should be included in the model. Risk may be incorporated directly into an expected utility formulation, after probabilities of different events have been assessed. It may be beneficial to construct scenarios representing the different possible outcomes for a specific alternative, to aid in the assessment of probabilities. An excellent description of methods for eliciting subjective probabilities is contained in Spetzler and Staël von Holstein (1975).

Stage Two: Gather Information

Information should be sought about the attributes of importance to the organization and about the performance of the alternatives on the attributes. It is assumed that the alternatives are available to the organization already.

Once a list of attributes is identified, the attributes should be examined for special properties. For example, if in the modeling stage a hierarchical representation of the attributes is chosen and an additive decision rule is proposed, then information should be sought to determine if these models are appropriate. The attributes may be tested for certain independence conditions such as preference independence and value independence. A discussion of these independence conditions is beyond the scope of this paper, but is included in Keeney and Raiffa (1976).

In assessing the attributes of importance to the organization, the opinions of more than one decision maker may be elicited. Surveys or committee meetings may serve as the data collection forum.

Ratnofsky and Corallo (1977) identify three broad categories of information sources: (1) previously published information, (2) information previously collected and available in raw form, and (3) information not previously collected. The sources are listed here in ascending order of cost and time requirements. Computer assisted methods may be used in all categories of information gathering.

Stage Three: Screen Alternatives

The many alternatives are screened by a process which requires less effort per alternative than does the more detailed evaluation which occurs in Stage Four. It is even possible that this stage will not be a major one, especially if the effort of fully evaluating each alternative is not unreasonable. Here, the set of potentially optimal alternatives is progressively refined through screening procedures.

First, threshold levels for all attributes are set. These levels should indicate the minimum acceptable performance by an alternative on each attribute. For example, in evaluating power plant sites, it is possible that the threshold on nearness to a major city is five miles; any proposed sites which are within a five mile radius of a major city would be immediately eliminated because they did not meet the minimum threshold value.

Alternatives may be sorted, especially if computerized data processing is available, into a number of sets for further study. The first sorting of alternatives might identify all alternatives which are 'good' or better in at least one attribute. For example, in Figure 2, job applicants 1, 3, and 4 meet this criterion. Then, further screening of this set might identify those who are 'great' on at least one attribute. Job applicants 1 and 4 in the figure would pass this further screening. This sorting technique can provide a means for identifying alternatives for special consideration.

Another method for reducing the set of alternatives is to check for attribute-by-attribute domination of alternatives. For example, if job applicant 1 in Figure 2 has a 'great' G.P.A., 'great' personality, and 'poor' references, then he will dominate applicant 4 with the same G.P.A., same references, and only a 'good' personality. Thus domination reduces the set of potentially optimal alternatives [Marschak (1976)], since we need no longer consider applicant 4.

	DETERMINANT ATTRIBUTES		
	GPA	Personality	References
Applicant 1	Great	Great	Poor
Applicant 2	OK	OK	OK
Applicant 3	OK	Poor	Good
Applicant 4	Great	Good	Poor

Figure 2. Illustration of Screening Procedures for Four Applicants Considering Three Determinant Attributes. Attributes are Ranked According to the Scale Great> Good>OK>Poor.

In addition to reducing the number of alternatives at this stage, it is possible to reduce the number of attributes by identifying the determinant attributes. Determinant attributes are those attributes which allow for discrimination among the feasible alternatives. If an attribute has the same value for each of the feasible alternatives, then it does not participate in discriminating among these alternatives. Operationally, a range of possible values for an attribute can be identified such that there is no important difference between the values, and this range would serve as a test for possible elimination of attributes. It must be pointed out that the attributes eliminated at this step may be determinant attributes in the future, so this screening procedure must occur after information about the current alternatives has been gathered. Thus, the set of determinant attributes may expand if another alternative is added to the opportunity set. Upon reducing the number of attributes, the alternatives should be rescreened, possibly some will be now eliminated. Similarly, after reducing the number of alternatives, some attributes may no longer be determinant. When no more eliminations can be made, the screening phase is completed.

Stage Four: Judge Feasible Alternatives

To judge feasible alternatives and make a satisfactory choice, four approaches are presented: developing an overall score for each alternative, qualitative judgements, portfolio-balancing of the chosen set of alternatives, and group decisions. For a specific problem, this stage may include combinations of these approaches, with modifications as may be needed.

Developing an Overall Score for Each Alternative Multiattribute utility theory provides a theoretical basis for developing scores for each alternative. The theory allows for either uncertainty or certainty about the outcomes of alternatives. The scores for alternatives are computed from a mathematical model. When certain independence conditions are met the mathematical model may be of a simple additive or multiplicative form. Keeney and Raiffa (1976) provide an excellent treatment of this topic.

Briefly, it may be possible to develop a score for each alternative i which is a weighted average of the form [Rubinstein (1975)].

$$V(\text{Alternative } i) = \sum_{j=1}^{m} C(i,j)r(j) \qquad (1)$$

where C(i,j) is the contribution of alternative i to the realization of attribute j, and r(j) is the rating of importance of attribute j.

To develop such a score begin with a relevance tree of attributes, for example the tree of Figure 3 for the problem of choosing a student financial aid program. At each node, non-negative relative weights of importance are assigned to the categories on the branches that emanate from the node. The sum of the weights is one. The relative importance of the attributes on the bottom of the tree are obtained by multiplying down the branches. For example, in Fugure 3, the rating of importance of the impace of the program on student preferences is 0.2 x 0.7 = .14.

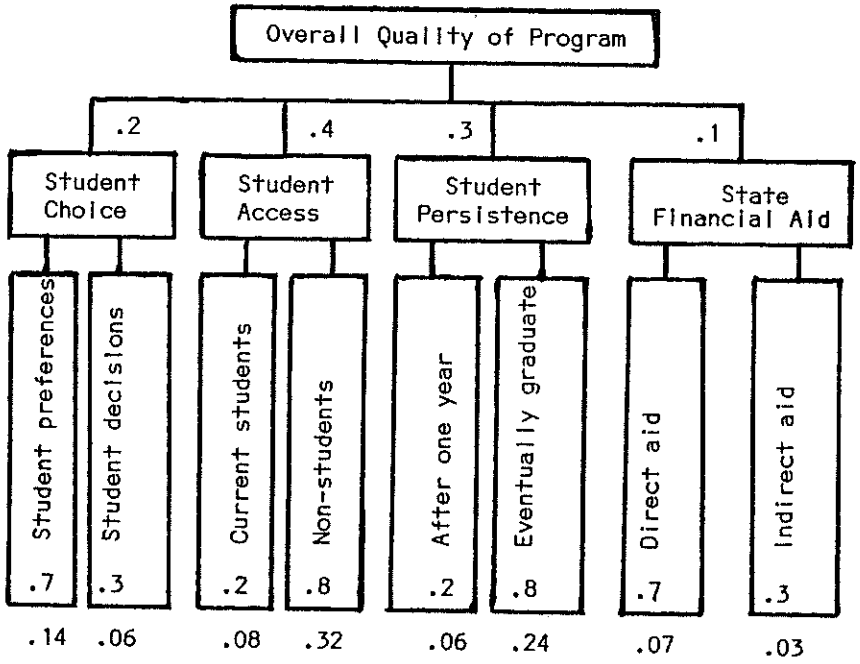

Figure 3: Relevance Tree for Ratings of Importance r(j) of Attributes.

The alternative choices are the three financial aid programs being evaluated. The goal is to come up with a score for each, then choose the program with the highest score for implementation. Each alternative i, (i = 1,2,3) is studied in terms of its contributions to each attribute j (j = 1,2,...,8)

value of each program i is obtained by multiplying the contributions C(i,j) by the rating of importance r(j) for each attribute j and taking the sum over all eight attributes, as represented by Equation 1.

There are many ways for assessing the relative weights of the attributes. Keeney and Raiffa (1976) present theoretically consistent methods. Approximations of weights have been made by using regression and factor analyses.

Qualitative Judgements Some decision makers are not comfortable with a method that generates an overall score for final choice even though the method uses information they supply about the attributes and the relative weights. They may prefer a more qualitative procedure that gives them the feeling of being more in control of the decision. Information on all the attribute ratings for all the alternatives can be supplied to the decision makers, requiring them to aggregate the data and choose among the alternatives. A method that might be in line with such qualitative judgement preference is to compare the non-dominated alternatives by the maximin approach. Each alternative is scanned for the lowest rating among all its attributes. The alternative with the highest minimum rating is chosen. The chosen alternative is guaranteed to be no worse than the maximin level on all determinant attributes [Rubinstein (1975)].

Portfolio-balancing of alternatives In choosing more than one alternative, certain properties of the "portfolio," or the combination of the chosen alternatives, may be desired. For example, a medical school may attempt to have a well-balanced class with various nationalities, backgrounds and medical interests represented.

It is possible to change perspectives, and view the multiple choice problem as one in which a single option is chosen. This is accomplished by defining an option as a set of alternatives. Thus the problem is now to choose one from among a set of options. In the medical school example, each option would be a proposed acceptance list, and the options might be evaluated on such attributes as racial representation and sexual balance. It must be noted that this perspective may become unwieldy due to the combinatorial nature of the problem. Despite this limitation, the representation provides a useful conceptual framework to visualize the problem.

Group decisions There may be many people, committees, or organizations jointly responsible for evaluating the alternatives. When there are multiple decision makers, the decision process model should explicitly identify the tasks of each,

One approach is to have each decision maker provide input to help develop one overall decision process, using techniques such as the Delphi method [Dalkey (1972)] and the Nominal Group Technique [Delbecq et al (1975)].

Another approach uses collective choice methods [Dyer and Miles (1976)] in which decision makers analyze the problem and judge the alternatives separately, and then submit these results to the group as a whole.

Stage Five: Announce Decision

This stage may be as simple as sending out letters of acceptance to students, or as complicated as entering complex contractual negotiations for a chosen program. Regardless of the level of complexity, attention should be paid to the implementation process. Often those responsible for choosing an alternative are not responsible for the follow-up implementation. It is important that there be procedures for phasing in, monitoring, and evaluating the chosen alternatives.

Contingency plans may be offered for chosen alternatives that are not successful. These contingencies may include waiting lists of alternate options, or a back up program already in existence.

An appeals process may be instituted to allow for reconsideration of rejected alternatives. An appeals procedure allows a margin of error in the original decision process, since decisions may be reversible.

It may also be of benefit to publicize the criteria by which decisions are made. This should lead to future submission of alternatives more compatible with the organization's objectives.

Stage Six: Evaluate the Decision Process

Measurements of how well a decision system works are necessary. One source for such measurements is a comparison among traditional methods and the new system. For example, in switching the California Coastal Commission ad hoc permit granting system to a proposed multiattribute weighting scheme, it has been suggested that both systems be run in parallel for comparison. The comparison can be made on such factors as ease of judgements, time and monetary expenses, and relative quality of accepted alternatives or programs. In fact the two methods, old and new, can be viewed as two alternatives and judged in terms of attributes by a process suggested by the framework here.

Often an evaluation of a system can extend beyond its limited boundaries. Viewing the entire organization, the following issues may be raised: Does the decision system facilitate communication among staff members on other issues? Does the system serve as a model for rational thinking in other administrative areas? Does the system hinder the productivity of the organization?

A system may receive a mixed evaluation. Many studies are never fully implemented. Decision makers may use only parts of the researched data or analysis [Keeney (1977), and Dyer and Miles (1976)]. At this point it becomes important to

evaluate the decision analysis process in terms of whether it was worth the expense. Often it is, even though not all results are used. The evaluation then serves as input into Stage One in the next round of decision making, in which a revision of the decision process may be made. Thus, the evaluation procedure provides an on-going basis for learning from the decision model. This learning has a value that could be formally included as an attribute in the evaluation.

SUMMARY AND CONCLUSION

The six stages of the framework proposed here are common to the evaluation of alternatives in a broad range of social problems. The stages range from initial modeling, through information gathering, screening and judging of alternatives, announcing the decision, and evaluating the decision process.

The decision model must be compatible with human decision makers. The decision process should not be delegated entirely to an expert or a computer for it to be used. The administrator responsible for the decision must be able to participate in the decision process at all stages, as proposed here.

Flexibility is inherent in the decision framework. In some problems, a qualitative judgement is appropriate for Stage Four, while in others a quantitative additive score is better. The evaluation in Stage Six provides a forum for on-going learning. This learning may even lead to revisions and improvements in the framework provided here.

A most appealing aspect of a rational approach to evaluating alternatives is the opportunity to establish decision rules, so organizations can spend more time clarifying objectives and less time repeatedly judging similar alternatives.

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