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Project Summary

d-SSYS, A Computer Model for the Evaluation of Competing Alternatives

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This study was instigated to develop a computer model that (a) quantitatively evaluates competing research and development projects, and (b) assists in prioritizing such projects when resources are not sufficient to conduct all of them. An evaluation model was developed, based upon existing multiattribute utility theory but with some modification and innovation. The model, with user input, helps determine the relative weights of the factors or criteria used to evaluate the projects under consideration, and, again with user input, determines the utility function for each of the attributes. A computer program was written to implement the model. A unique feature of this model is that it incorporates uncertainties of three types: (1) those dealing with the factor weights, (2) those dealing with the worth of each project with respect to each factor, and (3) those dealing with the utilities of the attributes. The model is adapted to run on personal computers as well as on larger ones, although the distribution version available is designed for personal computers. No special knowledge of the basic theory involved is required to exercise the computer model.

Although the study was designed with the objective of dealing with competing research and development projects, the model is sufficiently general so that it may be applied to any problem of competing alternatives. Thus, it has wide application in the health, engineering, environmental, and decision sciences.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

The Office of Research and Development of the United States Environmental Protection Agency, the firms under contract to it, and the recipients of the grants and cooperative agreements that it administers, are presently engaged in a broad program of research studies in a campaign to attack the pressing problems of hazardous waste minimization, containment, disposal, detoxification, and destruction. Resources, however, are limited and it not possible to fund every research study proposed. Furthermore, it is not uncommon for an individual research study to identify more than one solution to a particular environmental problem. Either situation involves the selection of a subset of alternatives from a larger set. In the first instance, the winning subset of alternatives consists of those studies that will be funded; in the latter, the winning subset consists of those solutions that will be recommended or implemented as oircumstances warrant.

The problem of determinating such winning subsets can be referred to simply as the "Evaluation of Competing Alternatives," or ECA for short. There are, however, two general types of ECA problems: (1) Best Subset and (2) Ranking. ECA best subset problems seek to select some subset of the complete set of alternatives that maximizes the worth of the subset while meeting one or more constraints placed upon the selection, whereas ECA ranking problems seek to determine an order of the alternatives according to worth. In ranking, worth can be measured on ordinal, interval or ratio scales, while the determination of the best subset requires a ratio scale.

Examples

As an example of a best subset problem, consider the set of three alternatives shown in Table 1 and assume that the goal is to fund as many of these projects as possible with a budget of $30,000. The solution, clearly, is to fund Alternatives 1 and 2. The problem could have been made more complicated by imposing an additional constraint, e.g., one involving time. Problems of this sort are generally solved using a technique known as "mathematical programming." However, with substantive problems, the technique is by no means trivial.

As an example of a ranking problem, suppose both cost and time are important and we have to pick a single project to fund. Given the data shown in Table 1, the solution is not clear. If 3-year completion time is too long for the results of the project to be useful, then perhaps only Alternative 2 should be funded. To clarify the decision-making for Criteria Set II, the two attributes, cost and time, must somehow be combined. This, however, involves an additional concept, i.e., that of the utility of money and the utility of time.

Table 1. *A Comparison of Three Alternatives*

Alternative	*Cost*	*Time*
1	*$10,000*	*3 years*
2	*$20,000*	*2 years*
3	*$40,000*	*1 year*

If we could combine the cost and time attributes of Table 1 into amalgamated units that express the collective worth of each alternative (these worth units will be called "Utility units"), we might arrive at the situation shown in Table 2. This is fine with regard to the ranking problem since Alternative 3 is now clearly the winner. Unfortunately, selecting a best subset using this new scale is not possible. We are not dealing with absolute worth (which requires a ratio scale) in Table 2 but with relative worth defined on an interval scale. Interval scales have certain properties (see Section B.1 of the full report). Adding the utilities of Alternatives 1 and 2 in Table 1, for example, produces the number 15 but it is not the *same* number as the 15 of Alternative 3. (Consider three employees with IQ's of 75, 75 and 150, respectively. Assigning the first two to a particular job may be a vastly different proposition from assigning only the third!) Thus, adding the utilities of alternatives under a utility budget constraint figure is logically flawed. In practice, however, this may not be a serious problem. Often, best subset problems are constrained solely by budget. One could simply select projects according to their ranking until the budgetary constraint was exceeded. This might leave some funds left over but often additional funds can be found to fund the next project or the remaining funds can be used profitably for some other purpose. The practical solution to ECA problems, therefore, is to consider them all simply as ranking problems.

Table 2. *A Comparison of Three Alternatives, the Criteria Converted to Utilities*

Alternative	*Utility Units*
1	*5*
2	*10*
3	*15*

Common Fallacies

Consider the following ECA model:

(a) Define factors or criteria;
(b) Weight the factors;
(c) Determine the value of each factor for each;
(d) Compute a score for each alternative by multiplying the factor score for each alternative by its corresponding factor weight.

As an example, consider the two-alternative, two-factor problem shown in Table 3. The Alternative scores would be calculated as follows:

Alternative 1: (0.2)(30) + (0.8)(20) = 22
Alternative 2: (0.2)(5) + (0.8)(25) = 21

Alternative 1, therefore, is superior to Alternative 2.

Table 3. *A Fallacious ECA Model*

Factor	*Alternative 1*	*Alternative 2*	*Factor Weight*
1	*30*	*5*	*0.2*
2	*20*	*25*	*0.8*

Suppose, however, that Factor 2 w measured in dollars. We now conv Factor 2 into some other unit of curren say pesos, by multiplying the Facto row by 100. (The other factors measured on different scales so th remain unchanged). The Alternat scores would become:

Alternative 1: (0.2)(30) + (0.8)(200) = 1
Alternative 2: (0.2)(5) + (0.8)(250) = 2

and Alternative 2 is now superior Alternative 1. This is illogical, howev since it shouldn't make any differen whether the scoring is done using doll or pesos. This is a common fallacy ECA models.

Results

The objective of this study was develop a cmoputerized model a procedure for the ranking of alternativ the requirements made on the mo were as follows. The model must:

(a) Produce a ranking of alternatives at least an interval scale;
(b) Be based upon sound decis theory;
(c) Be easy to understand and to use;
(d) Generate easily understood output
(e) Be usable on a wide variety computers, including perso computers; and
(f) Be able to deal with the uncertaint of its inputs.

The computerized model (called SSYS" for 'Decision Support Syster that resulted from this study meets al these requirements. It is a true decis support system, i.e., an interact system that provides the user with e access to decision models and data order to support semistructur decision-making tasks. Such a mo perforce must deal with subject judgments and often are criticized on t account. The truth of the matter is tha any decision-making process, a crit assessment of worth must be ma Even if we ensure that these judgme are made by those with a large store knowledge and a refined sensitivity to

;elevance, ultimately judgments *must* orm part of the process. What is 'equired of any model, however, is that it have a logically consistent assessment structure, hence the judgments made will be consistent. Furthermore, such models have the advantage of making explicit: (a) what factors were used to evaluate the alternatives, (b) the evaluator's view of the relative importance of the factors, and (c) the worth of each alternative with respect to each factor. A major fault of most conventional decision-making is that these matters are seldom made clear

The major testing of d-SSYS involved an actual application. The application concerned the evaluation of processes that have been proposed to deal with the problem of PCB-contaminated sediments. Eleven processes wre evaluated based upon six different classes of technologies. one on low-temperature oxidation, two on chlorine removal, one on pyrolysis, three on removing and concentrating, one on vitrification, and three on microorganisms. Seven factors or criteria were used to evaluate the 11 processes studied. The weights of these factors were assigned to emphasize the extent of decontamination, the estimated cost of treatment, and the versatility of the process The application of d-SSYS in this instance proved to be highly successful and was instrumental in the determination of the final recommendations of the PCB study.

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The complete report, entitled "d-SSYS, A Computer Model for the Evaluation of Competing Alternatives," (Order No. PB 88-234 182/AS; Cost: $14.95, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650

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