RM-77-31

APPLICATION OF A SIMPLE MULTIATTRIBUTE RATING TECHNIQUE TO EVALUATION OF NUCLEAR WASTE DISPOSAL SITES:

A DEMONSTRATION

Harry J. Otway[*]
Ward Edwards[**]

June 1977

[*] Project Leader, Joint IAEA/IIASA Research Project,
International Atomic Energy Agency, P.O. Box 590,
A-1011 Vienna, Austria.

[**] Director, Social Science Research Institute,
University of Southern California, USA.

PREFACE

Risks have emerged as an important constraint in the evaluation and selection of energy strategies. The work of the Joint IAEA/IIASA Research Project (IAEA: International Atomic Energy Agency) is oriented toward providing information on technological risks, and their social aspects, for use in decisions related to the management of risks. The emphasis of this research is upon energy systems.

This report presents results of a demonstration experiment which used public attitudes as one of the inputs in a decision related to the evaluation of hypothetical sites for nuclear waste disposals. This was a preliminary effort to explore the reaction of the decision-making group to alternative rating techniques and to the use of public attitude measures as a decision attribute.

ABSTRACT

Results are presented of a decision exercise to evaluate six hypothetical sites for nuclear waste disposal. The decision-making group were ten technical specialists who were attending an international meeting on this subject. Public attitudes toward the proposed sites were provided as one item of information. The suitability of alternative multiattribute rating techniques was explored; the participants chose a simplified method in preference to one based upon hypothetical multi-dimensional gambles. The decision-making group successfully used this simplified technique to aggregate technological and social issues in their decision.

INTRODUCTION

The continuation of a number of public debates about the acceptability of technologies suggests the difficulties which have been encountered in attempting to reconcile technological and social systems in public planning and decision processes. Technologists are often faced with the problem of equitably balancing complex technical data with the corresponding social attitudes. Aware of the importance of these attitudes, but unable either to measure them or to aggregate them with technical data, their recommendations are often based solely upon technical and engineering aspects. This, in effect, requires the ultimate decision makers, typically politicians, to assess the trade-offs between technical and social issues in a purely intuitive fashion.

The Joint IAEA/IIASA Research Project has developed a framework for risk assessment studies (see Otway, 1977, 1977a) to provide information on technological risks, and their social aspects, for use in risk management decisions. Of particular interest are methodologies for measurement of social attitudes toward technologies (see Otway and Fishbein, 1976) and the aggregation of these measures with technical information to help guide decision making. This report provides an illustration of an approach to the latter topic.

MULTIATTRIBUTE UTILITY MEASUREMENT

Decision analysts have long recognized that most social values are multidimensional, in the sense that several different aspects of whatever must be evaluated bear on its value. In the usual divide-and-conquer spirit of decision analysis, they have proposed approaches that, in effect, identify the various relevant dimensions of value, locate the objects to be evaluated on each dimension separately, determine single-dimension utilities for each dimension, and then aggregate these single-dimension utilities in a manner that appropriately reflects the importance of each. For more details of this complex set of ideas and procedures, see Raiffa (1969), Keeney and Raiffa (1976), Edwards (1972), and Edwards (in press).

In exploiting this technology the issue of the relation between modeling complexity and assessment technique is especially important. Simple additive aggregation rules permit quite simple assessment techniques for the numbers that enter into the aggregation process, but may poorly represent the underlying structure of the decision maker's preferences. The trade-off between errors produced by using an unduly simple preference model and errors produced by the additional time-consumingness and complexity of the assessment technique made necessary by more complex models has not been studied empirically, though Fishburn (1977), von Winterfeld and Fischer (1975), and Edwards (in press) have written about it. In addition, many of the theoretically more elegant assessment techniques depend on judgments of indifference between a gamble of the form "with probability p you win A, with probability 1 - p you win B" and receiving C for sure, where A, B, and C are all multiattribute consequences. Edwards, Guttentag and Snapper (1975) have expressed some doubt about the willingness of decision makers who are neither decision analysts themselves nor compelled to participate in a decision analysis to take such questions seriously. For that reason, they used Edwards' (1972) Simple Multi-Attribute Rating Technique (SMART). SMART depends on simple rating scales that seem to be considerably easier to understand than methods based on hypothetical multi-dimensional gambles.

This study had two purposes. One was to explore the use of multiattribute utility measurement, in either the Keeney-Raiffa or Edwards version, as a means for aggregating social with technological issues in a decision relevant to nuclear power. The other was to explore the acceptability of the two versions. Since the problem was imaginary, the data collection procedures were rather hurried and informal, and the options were not defined in depth prior to their evaluation, the data should not be taken seriously except as an illustration of the method. On the other hand, the respondents were high-level experts on the technological issues they were considering, so the information about method acceptability is relatively credible.

Method

Respondents. The study was conducted during the course of an international meeting of high-level technologists concerned with the problem of nuclear waste disposal. The ten participants included representatives from eight countries with advanced nuclear energy programmes. Since one topic of discussion was risk assessment of nuclear waste disposal, they were very much concerned with this problem and very co-operative. One of the authors (HJO) attended some sessions of the meeting, enlisted to co-operation of the respondents and was present throughout the data collection process.

Choice of Methods. Early and informal explorations of what experimental procedure might be acceptable yielded to clear message that the respondents did not wish to think about imaginary n-dimensional bets. Attempts to persuade some of them as individuals to try the Keeney-Raiffa method led to expressions of concern about the abstractness, difficulty, and lack of realism of thinking about hypothetical gambles over parameters of nuclear waste disposal sites. So this method was not used.

The Nature of SMART. The respondents were first given a brief introduction to the general idea of multiattribute utility measurement. To stimulate their interest in quantitative approaches to evaluation, they were given a brief summary of the psychological literature on cue utilization. The key points were that decision makers find it difficult to think simultaneously about all the dimensions relevant to a complex decision, and that subjects making holistic judgments often do not know what cues were actually important in controlling their judgments. They seemed receptive to the idea that a somewhat formal evaluation procedure could help to ensure that all relevant dimensions of evaluation are used, and used consistently in a pre-determined manner.

The technical steps of SMART (see Edwards, 1973; in press; Edwards, Guttentag, and Snapper, 1975) are the following:

1. Elicit an appropriate number of dimensions of value relevant to evaluating the options on hand.

2. Judge importance weights, by a method to be described in context below. The importance weight of the ith dimension of value will be symbolized W_i; for convenience the arbitrary convention will be used that $\sum W_i = 1$.

3. Ascertain upper and lower bounds on the physical measure (if any) that define the value dimensions.

4. Select upper and lower bounds for the single-dimension utilities associated with each value dimension. For convenience the least attractive point of each single-dimension scale is called 0 and the most attractive point is called 100. The literature is somewhat confused about whether this normalization should run from least to most attractive feasible points or from least to most attractive points among the set actually available; the question will be explored in the data analysis.

5. Assign single-dimension utilities between the upper and lower bounds on each scale. The simplest method of doing this is to ask the respondent simply to draw a graph of his single-dimension utility function. Often, that graph will be approximately or even exactly linear. The utility of the jth object to be evaluated on the ith dimension of value will be called u_{ij}, $0 \leq u_{ij} \leq 100$.

6. Calculate the utility of the jth object to be evaluated from the equation $U_j = \sum_i W_i u_{ij}$.

7. The values of U_j are appropriate inputs to a decision-making process, either formal (maximization of expected utility) or informal.

Elicitation of Value Dimensions. After the respondents had been briefed about the method, the experimenter proposed, as Dimension 1, public attitude toward the waste disposal site. All respondents accepted it as relevant and important. To get the discussion going, the experimenter next proposed, as Dimension 2, remoteness of the site from a population center. Thereafter, the participants proposed four more dimensions and, after some prodding, one more; at this point the set of salient dimensions had obviously been exhausted. The full list, in the order in which they were elicited and with scaling, is:

D1. Public attitude toward the waste disposal site. A highly favourable attitude scores 100; a highly unfavourable one scores 0.

D2. Remoteness of the waste disposal sites from a population center, in km. 160 km scores 100; 0 km scores 0.

D3. Geospheric path length, in km. The distance from the location of the radio-active waste in the geological formation to the nearest point in the environment used by the public. 160 km scores 100; 0 km scores 0.

D4. Proximity of the waste disposal site to natural resources (e.g., mines, recreation areas, etc.). 160 km scores 100; 0 km scores 0.

D5. Geologic disturbance probability (e.g., yearly probability of a significant earthquake). 10^{-6} scores 100; 1 scores 0.

D6. Relative migration rate of critical nuclide. This is the rate of migration of the critical nuclide in the geological formation, allowing for adsorption and desorption, compared with the rate of movement of the ground water (assumed constant at 0.3 m/day). Since this dimension is a ratio, it has no units; 10^{-5} scores 100; 1 scores 0.

D7. Transportation distance between nuclear plant and waste disposal site. 0 km scores 100; 1600 km scores 0. (This scaling suggests the desirability of storing wastes at the site where they are created.)

Note that all dimensions are transformed into the 0 - 100 scale in such a fashion that higher scores are preferable to lower ones. Respondents readily agreed among themselves that a linear relationship between physical measures and single-dimension utility (u_{ij}) was a reasonable approximation. In the case of D5 and D6, the linearity is with the exponent, not the number itself.

In retrospect, several features of the scaling of the dimensions were questionable. Most obvious is the use of 1 as the highest probability of an earthquake in a year. No one would seriously propose a nuclear waste disposal site with so high an earthquake probability; a lower probability should have been used as the upper bound.

Assessment of Importance Weights. Edwards (in press) specifies the method used to collect the importance weights. In his method, the dimensions are first rank-ordered from most to least important. Ties are permitted. Then the least important dimension receives an arbitrary weight of 10. (Use of 10 rather than 1 permits respondents to judge ratios smaller than 2:1 while still expressing their judgments in integers.) Each dimension above the least important one is then assigned some number ≤ 10; the ratio of that number to 10 specifies its importance compared with that of the least important dimension. Cross-checks can be made by comparing dimensions with one another; all ratios of dimension weights should be consistent. That is, if D4 has a weight of 15 and D5 a weight of 45, then D5 should be judged three times as important as D4. If necessary, initial judgments should be revised to produce this internal consistency. Finally, the judged ratios are normalized to sum to 1.

This procedure was repeated twice on different days. Of the 10 respondents available on the first day, all but one were also present on the second day.

Invention of Hypothetical Waste Disposal Sites. At this point, all information necessary to carry out SMART calculations was in hand--but there were no waste disposal sites to evaluate. So one of the experts at the conference volunteered to invent some; he did so by thinking of real sites that had been suggested for the purpose, and using approximate figures for the relevant physical parameters. The basic assumptions involved were that geologic disposal would be used for the accumulated high-level wastes from a national nuclear power economy through the year 2000 as well as all tritium, carbon, iodine from the spent fuel and all activation products from the cladding. This was estimated to be 1.38×10^{10} Curies of fission products and 1.61×10^{9} Curies of actinides. The sites were assumed to have the same typical local biosphere. The time for the dissolution of the waste form was taken to be 100 years if contacted by water; the ground water velocity was assumed to be constant at 0.3 m/day for all sites (for a discussion of geologic waste disposal, see Burkholder, 1976). It is important to note that all sites were postulated to fall within budget constraints. Public attitudes toward the hypothetical waste disposal sites were assigned on a random basis. Table 1 provides the site descriptions.

Respondents then made holistic evaluations of the attractiveness of each site on a 0 - 100 scale, for comparison with the SMART evaluations.

RESULTS AND DISCUSSION

Importance Weights. Since the importance weights of the seven value dimensions were judged twice by all but one of the respondents, test-retest reliability of these judgments could be calculated. Correlations between first and second judgments were very high. The mean correlation was .93 (standard deviation was .11), and the lowest was .65. For convenience, the second set of weights is used in all subsequent calculations, except for those of the respondent who made only one set of judgments.

The inter-respondent agreement about importance weights was, as expected, much lower. Correlations among second-judgment weights between pairs of respondents range from +.97 to -.27. The mean correlation was +.39 (standard deviation was .35). This is consistent with other applications of SMART. Edwards (in press) has argued that individual differences in values should show up primarily in assessments of importance; single-dimension utilities are often technical judgments rather than value judgments.

To perform subsequent SMART calculations, the mean importance weights were calculated. The first column of Table 2 shows these means. The second column shows the standard deviation of each mean over respondents, and the third shows the ratio of the standard deviation to the mean. Inspection of the third column shows, not surprisingly, that the lower means also have lower standard deviations. This is a common finding in applications of SMART. It could be interpreted as meaning simply that smaller numbers have smaller standard deviations, or as implying that in order to get a really small importance weight, respondents must agree that a value dimension is unimportant. Both interpretations are correct; the second implies the first.

SMART Arithmetic. Inspection of Table 1 and of the scaling on the list of dimensions shows that the sites evaluated by no means covered the plausible range of the dimensions of value. D3's range covers only 22.5% of the range assigned to it. This can easily happen in situations, such as this one, in which an evaluation scheme is developed before the entities to be evaluated are known. Yet, exactly that must often be done.

The reason why this presents a problem is that the range of u_{ij} values of a value dimension is in a sense a kind of importance weight. A dimension whose u_{ij} values range from 0 to 50 is effectively only half as important in controlling evaluation as one having the same W_i whose u_{ij} values range from 0 to 100.

While this problem can be solved only by judgmental methods, it can be put into a simple perspective by a little arithmetic. Consider the following transformations:

$$u'_{ij} = 100(u_{ij} - M_i)/R_i \quad (1)$$

$$W'_i = W_i R_i/S \quad , \quad \text{where } S = \sum W_i R_i \quad (2)$$

R_i is the range of u_{ij} in dimension i over the set of entities to be evaluated. M_i is the minimum value of u_{ij} over those entities in dimension i. So u'_{ij} will have a minimum value of 0 and a maximum of 100 on each dimension, over the set of entities to be evaluated.

The weights W'_i will not be the same as W_i, but they will be normalized and sum to 1. A little algebra will show that

$$U'_j = \sum_i W'_i u'_{ij} = (100/S) \sum_i W_i u_{ij} - (100/S) \sum_i W_i M_i \quad .$$

In other words, U'_j is a positive linear transformation of U_j. Since any positive linear transformation of a utility function is also a utility function, the transformed values are as appropriate for decision making as the original ones were. However, the effect of the transformation is to put all of the scaling information into the W'_i--at least as it applies to the set of entities at hand. An appropriate elicitation procedure, not used in this case, would be to retransform the W'_i values into a set of ratios such as was elicited in the initial evaluation, and then go back to the respondents with the u'_{ij} and W'_i values and inquire whether they are satisifed with them. If they are, the values of either U'_j or U_j can be used as appropriate inputs to a decision. If not, they can revise the ratios until they are again satisfied. In the latter case, the revised ratios must, of course, be used in conjunction with u'_{ij}, not u_{ij}.

The fourth column of Table 2 presents the values of W'_i calculated from the W_i values in the first column of Table 2 and the ranges of the hypothetical sites. Table 3 shows the values of u'_{ij}, which are easier to inspect that those of u_{ij}. Table 3 also shows the value of $U'_j = \sum_i W'_i u'_{ij}$ for each site.

The first thing to notice about Table 3 is that, if the choice were restricted to either site 2 or site 3, no one could possibly pick site 3. In technical jargon, site 2 dominates site 3; that is, 2 is at least as good as 3 on very dimension, and definitely better on at least one. Note that no other site is dominated. Also note that site 6, though evaluated as best by the weighted utility criterion, does not dominate site 3; site 3 is better than site 6 on dimensions 4 and 6.

If decision making were the only goal of the analysis, it would be appropriate to delete site 3 from all further calculations. But for other purposes, in particular the study of environmental correlations among dimensions as they affect SMART, it is useful to have as many stimuli as possible. For that reason, site 3 is retained in all subsequent calculations, even though it is dominated.

Clearly, site 6 is best and site 3 is worst. The spread in utility between best and worst is modest but acceptable, considering the scale and the disagreement among judges.

Table 3 also permits explorations of the effect of scaling problems on SMART. Values of the inappropriate quantity $\sum_i W_i u'_{ij}$ are tabulated. The effect of scaling u_{ij} has been removed from u'_{ij}, but is not included in W_i. Again, site 6 is best. Two inversions of ordering have occurred; sites 1 and 2 and sites 4 and 3 have been interchanged. However, the correlation between $\sum_i W'_i u'_{ij}$ and $\sum_i W_i u'_{ij}$ is +.87. This high correlation indicates that the effect of the scaling issues is minor, though discernible. If site 6 were not present, site 1 rather than site 2 would be preferred by the inappropriate calculation, but this calculation represents a worst case, since it assumes that respondents paid no attention to scaling of the dimensions in choosing importance weights.*

---

*Prof. Amos Tversky has suggested to us an alternative to the procedure involving u'_{ij} and W'_i. Rather than attempting to use an upper and a lower bound that are sure to include the range of variation of each dimension, he suggests that one might take advantage of the linear structure of this multi-attribute utility model by selecting upper and lower values that, though separate enough to be clearly distinguishable in attractiveness, are close enough to that the range on each dimension will be greater than the chosen values. Then the respondent must pay attention to the actual values selected in making is weighting judgments. This procedure is linear or nearly so with some underlying physical dimension, as in this demonstration. But it does present a problem: can respondents properly take such boundaries into account in judging values of W_j? Such questions obviously need experimental answers, and have not yet received them.

Intercorrelations Among Value Dimensions. The additive model being used here assumes that the value dimensions do not interact in preference; that is, that a given value of D1 contributes the same amount to total utility regardless of the values of the other dimensions. This strong assumption is bound to be wrong in detail, but it permits simple calculations and gives an excellent approximation to other more complicated models, especially if the value dimensions are conditionally monotonic (i.e., either more on a dimension is preferred to less or less is preferred to more regardless of values of the other dimensions), as they all are in this case. (For discussions of this topic, see Dawes and Corrigan, 1974; Wainer, 1976; Yntema and Torgerson, 1961).

But the environmental correlations among value dimensions are also important. Table 4 shows those intercorrelations for the six hypothetical sites.

The very high correlation between D1 and D4 would imply that one of these dimensions could be omitted from the analysis, if the correlation were positive. Since it is negative, it implies that D1 and D4 affect preference in opposite directions. Inspection of the W'_i column of Table 2 indicates that this is unfortunate and helps to explain the relatively close clustering of sites in Table 3. After scaling factors are taken into account, D1 and D4 virtually cancel each other out. It seems likely that, if the respondents had been presented with Tables 2, 3, and 4 and this fact had been pointed out to them, they would have wished to change their judgments in some appropriate way. It is certainly an unlucky accident that random assignment of values for D1 should have produced this high negative correlation with the other most important dimension. Rare events happen, though rarely.

If a variable is omitted from a multiattribute utility analysis because it is highly positively correlated with another variable, its importance should be added to the importance of that other variable. In effect, the retained variable becomes a proxy for the omitted one.

Holistic Judgments. Table 5 presents the holistic ratings for all sites by all respondents. The inter-respondent agreement in these ratings is smaller than it was for the importance weight judgments. The mean correlation between pairs of respondents is +.20 (standard deviation is .475); the range is from +.97 to -.55. The comparable figures for weights are +.39 (standard deviation is .35) and +.97 to -.27. It is encouraging but not especially surprising that there is, if anything, more inter-respondent agreement about importance weights than about direct evaluations. The correlation between mean holistic ratings and SMART ratings is +.58. Both procedures consider site 6 best and site 3 worst. This correlation between SMART and holistic ratings is rather high compared with most other such correlations in the multiattribute utility literature. After all, there would be no point in procedures like SMART if direct numerical assessments produced the same results.

Table 5 shows with holistic ratings, as was also true for importance weights, a high correlation (+.94) between mean and standard deviation, for essentially the same reason.

A Hypothetical Calculation. Suppose the random assignment of public attitudes to sites had come out differently, how would the analysis have looked? W_i and W'_i would be unaffected. Only the first line of Table 4 would be different. But the final result would be quite different. Particularly interesting, of course, would be an assignment of public attitudes to sites that would correlate exactly 0 with D4. Using the same values that were originally used, but assigning them to different sites, such an assignment is possible. Table 6 shows what the changes would have been.

The effect is certainly substantial. The spread between highest and lowest value of U'_j increases from 19.7 to 40.2. S3, which scores 100 on D1'. is now the winner, and S6 comes in second. S5, which was previously next-to-last, now comes last.

Of course, it is not appropriate to compare these new values of U'_j with the holistic ratings, since those ratings were collected on the basis of the old assignment of D1. But the fact that a change in D1 can produce such substantial changes in the evaluation of sites shows again that multiattribute utility measurement techniques can combine such information with technological information in a decision process, giving judgmentally appropriate weights to both kinds of information.

An Approach to Resolving Interpersonal Disagreement. In a situation characterized by disagreement among experts, like this one, it would probably be appropriate to go back to the experts with the tables of ratios implied both by the original averaged importance judgments and by the rescaled values of W'_i. In a sense, these numbers are what the experts are disagreeing about; they capture the essence of their disagreements (provided there are no significant disagreement about the u_{ij}) in numercial form. Agreement to a single set of such numbers is tantamount to a compromise among conflicting value systems. It is therefore instructive to look at the systems of ratios implied both by the mean W_i values and by the W'_i values calculated from them. Table 7 shows these ratios, multiplied by 10 to conform to the elicitation procedure.

So far as we are aware, no attempt has yet been made to use this technique of feeding back the ratios of importances to the experts from whose judgments they were calculated. It might turn out to be a useful approach to resolving conflicts about evaluations.

ACKNOWLEDGEMENT

The authors wish to thank Dr. Harry C. Burkholder, Battelle Pacific Northwest Laboratories, for his help in constructing the technical descriptions of the nuclear waste disposal sites used in this experiment.

TABLE 1

Description of Six Hypothetical Nuclear Waste Disposal Sites

Value Dimension, Range, and Scaling	Site 1	Site 2	Site 3	Site 4	Site 5	Site 6
D1. Public attitude. 0 = extremely negative; 100 = extremely positive	40	20	10	40	60	70
D2. Remoteness from population center, km. (0 km = 0; 160 km = 100).	40	12	12	120	40	120
D3. Geospheric path length, km (0 km = 0; 160 km = 100)	40	12	12	4	4	40
D4. Proximity to natural resources, km. (0 km = 0; 160 km = 100)	50	150	50	50	15	15
D5. Geologic disturbance probability per year (1 = 0; 10^{-6} = 100; linear in exponent)	10^{-4}	10^{-5}	10^{-4}	10^{-6}	10^{-5}	10^{-6}
D6. Relative migration rate of critical nuclide (1 = 0; 10^{-5} = 100; linear in exponent)	10^{-3}	10^{-3}	10^{-2}	10^{-1}	10^{-2}	10^{-1}
D7. Tranportation distance, km. (1600 km = 0; 0 km = 100)	1500	500	500	1500	150	150

TABLE 2

Mean Importance Weights and Their Standard Deviations

Value Dimension D_i	W_i	$\sigma(W_i)$	$\sigma(W_i)/W_i$	W'_i
D1. Public attitude	.200	.161	.80	.246
D2. Distance from city	.063	.044	.70	.087
D3. Geospheric path length	.191	.094	.49	.088
D4. Proximity to natural resources	.554	.099	.64	.267
D5. Earthquake probability	.176	.061	.35	.103
D6. Migration of critical nuclide	.186	.077	.41	.153
D7. Transportation distance	.032	.022	.69	.055

TABLE 3

Values of u'_{ij}, $\sum_i W'_i u'_{ij}$, and $\sum_i W_i u'_{ij}$

Dimensions	Sites					
	S1	S2	S3	S4	S5	S6
D1	50	16.7	0	50	83.3	100
D2	25.9	0	0	100	25.9	100
D3	100	22.5	22.2	0	0	100
D4	25.9	100	100	25.9	0	0
D5	0	50	0	100	50	100
D6	100	100	50	0	50	0
D7	0	74.1	74.1	0	100	100
$\sum_i W'_i u'_{ij}$	45.6	57.3	40.4	38.2	41.0	51.9
$\sum_i W_i u'_{ij}$	53.3	52.8	31.3	37.9	39.6	66.2

TABLE 4

Intercorrelations of Value Dimensions With One Another

	D2	D3	D4	D5	D6	D7
D1	.66	.35	-.94	.59	-.49	.24
D2		.21	-.67	.84	-.84	-.18
D3			-.30	-.11	.11	-.09
D4				-.48	.48	.02
D5					-.75	.12
D6						-.12

TABLE 5

Holistic Ratings of Sites

Respondent	Site					
	S1	S2	S3	S4	S5	S6
A	40	30	20	60	80	90
B	50	40	30	50	30	30
C	60	70	10	40	50	100
D	70	60	40	10	30	30
E	40	55	45	50	50	60
F	30	20	20	40	50	70
G	80	10	15	50	60	50
H	40	40	20	50	90	80
I	40	50	15	20	30	100
J	80	60	40	20	40	40
Mean	53.0	43.5	25.5	39.0	51.0	65.0
Standard Deviation	18.3	19.2	12.4	16.6	20.8	27.2
SD/Mean	.35	.44	.48	.43	.41	.42

TABLE 6

Effects of a New Assignment of Public Attitudes to Sites

6a. The New Assignment

	S1	S2	S3	S4	S5	S6
D1'	50	0	100	50	16.7	83.3

6b. Effect on U'_j of New Assignment of D1

U'_j	45.6	53.2	64.9	38.2	24.7	53.8

6c. Effect on Correlations with Other Value Dimensions

	D1	D2	D3	D4	D5	D6	D7
D1'	-.39	.28	.37	0.00	-.10	-.49	0.00

TABLE 7

Ratios (x10) of W_i and W'_i Values

Ratios of W_i Values

	D7	D2	D4	D5	D6	D3
D1	62.5	31.7	13.0	11.4	10.8	10.5
D3	59.7	30.3	12.4	10.9	10.3	
D6	58.1	29.5	12.1	10.6		
D5	55.0	27.9	11.4			
D4	48.1	24.4				
D2	19.7					
D7	10					

Ratios of W'_i Values

	D7	D2	D3	D5	D6	D1
D4	48.5	30.7	30.3	25.9	17.5	10.9
D1	44.7	28.3	28.8	23.9	16.1	
D6	27.8	17.6	17.4	14.9		
D5	18.7	11.8	11.7			
D3	16.0	10.1				
D2	15.8					
D7	10					

References

Burkholder, H.C. (1976), *Methods and Data for Predicting Nuclide Migration in Geologic Media,* Proceedings of the International Symposium on the Management of Wastes from the LWR Fuel Cycle, Conference-76-0701, US Energy Research and Development Administration.

Dawes, R.M., and B. Corrigan (1974), Linear Models in Decision Making, *Psychological Bulletin,* 81, 95-106.

Edwards, W. (1972), Social Utilities, in *Decision and Risk Analysis: Powerful New Tools for Management,* Proceedings of the Sixth Triennial Symposium, June, 1971, Hoboken, N.J., The Engineering Economist, 119-129.

Edwards, W. (1977), Public Values: Multiattribute Utility Measurement for Social Decision Making, *IEEE Transactions on Systems, Man, and Cybernetics,* in press.

Edwards, W., M. Guttentag, and K. Snapper (1975), Effective Evaluation: A Decision Theoretic Approach, in Streuning, E.L., and M. Guttentag, eds., *Handbook of Evaluation Research,* Vol. I, Beverly Hills, CA., Sage Publications.

Fishburn, P.C. (1977), Approximations of Two-Attribute Utility Functions, *Mathematics of Operations Research,* Vol. II, No. 1, in press.

Keeney, R.L., and H. Raiffa (1976), *Decisions with Multiple Objectives: Preferences and Value Tradeoffs,* New York, Wiley.

Otway, H.J. (1977), *The Status of Risk Assessment,* presented at the 10th International TNO Conference on Risk Analysis: Industry, Government and Society, 24-25 February, 1977, Rotterdam, Netherlands. To be published in proceedings.

Otway, H.J. (1977), *A Review of Research on the Identification of Factors Influencing the Social Response to Technological Risks,* to be presented at the IAEA Conference on Nuclear Power and Its Fuel Cycle, 2-13 May, 1977, Salzburg, Austria. To be published in proceedings.

Otway, H.J., and M. Fishbein (1976), *The Determinants of Attitude Formation: An Application to Nuclear Power,* RM-76-80, International Institute for Applied Systems Analysis, Laxenburg, Austria.

Raiffa, H. (1969), *Preferences for Multi-Attributed Alternatives*, RM-5868-DOT/RC, Santa Monica, CA, The Rand Corporation.

von Winterfeld, D., and G.W. Fischer (1975), Multi-Attribute Utility Theory: Models and Assessment Procedures, in Wendt, D., and C.A.J. Vlek, eds., *Utility, Probability, and Human Decision Making*, Dordrecht, the Netherlands, Reidel.

Wainer, H. (1976), Estimating Coefficients in Linear Models: It Don't Make No Nevermind, *Psychological Bulletin*, 83, 213-217.

Yntema, D.B., and W.S. Togerson (1961), Man-Computer Cooperation in Decisions Requiring Common Sense, *IRE Transactions on Human Factors in Electronics*, HFE-2, 20-26.