CORNELL
AGRICULTURAL ECONOMICS
STAFF PAPER

DECISION ANALYSIS AS A TOOL FOR SELECTING EVALUATION SCHEMES*

by

Hugh R. Alley and Jon M. Conrad

June 1983

No. 83-12

Department of Agricultural Economics
Cornell University Agricultural Experiment Station
New York State College of Agriculture and Life Sciences
A Statutory College of the State University
Cornell University, Ithaca, New York, 14853

DECISION ANALYSIS AS A TOOL FOR SELECTING EVALUATION SCHEMES*

BY

Hugh R. Alley and Jon M. Conrad

---

* This paper was prepared for presentation at the Annual Conference of the National Association of Environmental Professionals held in Detroit, Michigan, April 24-27, 1983.

Hugh Alley is a consulting resource economist and a former graduate student and Jon Conrad is an Associate Professor of Resource Economics at Cornell University, Ithaca, New York. The authors would like to thank Doug T. Gillespie and Timothy J. F. Lash of the Canadian Wildlife Service, Rich Malecki and David J. Allee of Cornell University, and, for editorial assistance, Daphne E. Alley, Toronto, Canada.

DECISION ANALYSIS AS A TOOL FOR SELECTING EVALUATION SCHEMES

ABSTRACT

The evaluation of natural areas for preservation has a number of associated bureaucratic and political needs which must be acknowledged as an evaluation scheme is created. These center on needs for defensibility of the scheme, lack of ambiguity, predictability in application, and avoidance of excessive costs during evaluation. Decision analys is a set of tools for reducing uncertainty about preferences and can address the above needs. There have been two major themes in decision analysis, one motivated by concerns for theoretic correctness, and one motivated by concerns about the cognitive abilities of participants. Case studies have tended to adopt one of the two approaches without a comparative assessment of both. This study is the first to report on a comparison of the two approaches to the same problem, and is done in the context of a repetitive decision.

The case reported was carried out at the national headquarters of the Canadian Wildlife Service where they are concerned about preserving wetlands because of a mandate to protect migratory birds. Over eleven days, the objectives of the evaluation were defined, contributing values and features to measure them were identified, conditional value functions were obtained, a preference structure for aggregating values was elicited, and weights, or ratings, for the additive features were obtained. In the last three steps, which are independent of each other, the two different approaches were examined. The approach to the first two steps is common to both. The theoretically rigourous approach could not be made to provide results for either the conditional value functions or the ratings of additive features within the time available, while the simpler Edwards approach produced results in these two steps. Results were obtained from both approaches to aggregation. However, the more rigourous approach, which did not assume that the values of the features could be simply added, was chosen by the respondent as better reflecting his preferences.

The study showed that the concern for the cognitive complexity of the rigorous approaches to preference elicitation were well founded. The study supports theoretic results that the functional form of an evaluation scheme is more critical to the effectiveness of a scheme than the weights associated with the additive features. The study demonstrated the importance of considering who was participating in the process because different people have different interests. The importance of clear definitions of objectives and of features to reduce any misleading difference in preferences is noted. The process encourages creativity in the respondents, helping them look at their interests in new ways. This creativity supports the value of decision analysis as an aid to negotiation between individuals or agencies about differences in interests. The study indicates that decision analysis can be a helpful approach for selecting a natural area evaluation scheme.

DECISION ANALYSIS AS A TOOL FOR SELECTING EVALUATION SCHEMES

INTRODUCTION

As the pressure on natural ecosystems in our landscape grows, there is an increasingly recognized need to protect and preserve some portions of these ecosystems. Two major questions arise as this is considered. The first of these is how much is to be preserved, and the second is which of the many possible areas are to be chosen. This study was directed at the second of these. Once how much is to be preserved has been decided, some defensible method of choosing which areas are to be preserved is necessary. The interest is to obtain the greatest value for the resources spent. The political decision makers require defensibility in order to continue their support of the agencies involved. Yet they need some flexibility to accommodate unforseen shifts in public opinion. And bureaucrats require an inexpensive and predictable decision process.

All these issues combine to establish the framework within which decisions will be made, and they all point to the use of an evaluation scheme of some sort. Evaluation schemes are an attempt to capture a set of value judgements and combine them in a way that is known, defensible, and predictable. This paper examines the use of a set of tools called 'decision analysis' to create a wetland evaluation scheme that meets the needs of decision makers.

Decision analysis is, in essence, a set of tools to help clarify a decision maker's preferences. It has two major forms; one considers preferences when the outcomes associated with a particular decision are known for sure, and one considers preferences when the associated outcomes can only be described in terms of probabilities. If a wetland is chosen for preservation, then the results are certain: a variety of benefits provided by the wetland will continue indefinitely. Uncertainty about the valuation of those benefits does not alter their continued provision, and so for wetlands, the outcomes of choices for preservation may be considered sure, or certain.

The approach of decision analysis has four general steps similiar to any system analysis; 1) identification of the objective of the evaluation, 2) identification of elements of the objective and definition of features to describe those elements, 3) elicitation of a conditional value function for each feature, and 4) elicitation of the appropriate aggregation structure for the feature values.1/ What identifies decision analysis is not the general steps, but the tools brought to bear in the last two steps.

There is variety even within the label 'decision analysis'. There are, in essence, two schools. One, herein referred to as the Rigourous approach, argues that any departure from theoretic purity must be justified. Its practicioners recognize the problem of obtaining accurate, repeatable answers, so they have developed a variety of simplifying assumptions and fairly straight-forward tests for justifying those assumptions(see Keeney and Raiffa, 1976). The other approach will be referred to as the Edwards approach after one of its important proponents. It argues that errors from departures from theoretic purity

---

1/ A conditional value function is a function indicating the relative value of all plausible levels of any feature, conditional on all features being held at constant levels. There is a parallel with the definition of conditional probability functions. Since value scales are arbitrary the scales are normally assumed to run from zero for the least desirable measure of the feature to one for the most desired measure of the feature over the plausible range of feature levels.

are not nearly as prejudicial to good results as errors from difficulties in understanding the complexities of theoretically correct questions. Consequently, practicioners argue that the process must be kept sufficiently simple to avoid cognitive difficulties.

Reports of applications of both approaches are found in the literature, and both seem capable of producing useful results (Bell, 1977; Edwards, 1977; Smallwood and Morris, 1980; Ulvila and Snider, 1980). The time requirement of the Rigourous approach is much higher, taking as much as six months of intensive work with the decision maker. Reports of the Edwards approach suggest that three to six days are sufficient for the simpler approach. No report in the literature has been found of an attempt to use both approaches in one case and compare the results. Note, however, that the two approaches are not monolithic, since each stage of the analysis is independent. Elements from each approach can be combined to get results in a variety of ways.

This paper considers the use of decision analysis in the selection of a wetland evaluation scheme. It examines the workability of the various elements of the two approaches, and briefly examines the sensitivity of the results to errors in the questioning procedures. The study was done in cooperation with officials in the Migratory Birds Branch of the Canadian Wildlife Service (CWS), especially the National Habitat Co-ordinator, who are responsible for preserving wetland habitats for the values from use by migratory birds.

APPLICATION

The study was carried out at the headquarters of CWS in Hull, Quebec, over a period of 11 working days in April, 1982. The primary contact was with the National Habitat Co-ordinator in ten daily sessions of an hour or less. Six other members of the CWS national staff were interviewed at various times, three of them more than once. Interviews with other staff were largely for background information, secondarily for other views of features to be included, and in one case, to provide another ranking of the selected features.

Defining Objectives and Features

The initial steps of defining the objective and identifying features to be included were largely completed over the first five days. Since the Ontario Region of CWS had just written a draft wetland evaluation scheme, the features contained in it were used as an initial feature set for consideration. The respondent decided to limit the features he considered to those associated with biological poductivity and diversity. Although the respondent acknowledged the wetland values associated with hydrological and social/cultural features, he felt that the mandate of the Migratory Birds Branch precluded considering these values in its evaluation of wetlands. After the first day's discussions, the respondent ofered a list of concerns or values he associated with wetlands in light of his mandate. Discussions over the next four days clarified some values, added new ones, and combined or discarded others. The process of identifying objectives and features is iterative: this became clear when even in the midst of later stages of the analysis, new features for inclusion were considered and some features were dropped.

Prompting the respondent to consider anew what elements of wetlands were important, how they could be measured, and what an evaluation was to accomplish encouraged his creativity. For example, he suggested a measure of a wetland uniqueness based on some classification work of the Lands Directorate of Environment Canada, reducing costs by using work already done by another branch of the government. Another example of this creativity was the respondent's articulation of four issues considered in decisions to protect natural areas ((1) ecological value, (2) threats from other land use practices, (3) its availability for purchase, and (4) provincial agreement to the purchase). By recognizing these elements, it became clear to the respondent that the objective of the evaluation scheme was the consideration of the first two issues, providing a measure of the need for protection. With a clear statement of the objective, the respondent could decide more easily if including any given feature was appropriate. Thus one of the strengths of the process was how much it could help the respondent clarify his interests.

The set of features arrived at after the fourth day of discussions is shown in Figure 1. At this stage, measurable features for all but one value had been chosen, but no attention had been given to the conditional value functions or aggregation. The next step was to check that the features were all essential and workable. One feature was discarded because it was recognized as a policy issue (representativeness of the wetland in the region; if representative examples of each wetland are wanted, the decision can be made independently of the evaluation scheme.) The measures for two of the features were not intuitively clear, preventing development of conditional value functions, so these features, too, were discarded. Four features were discarded at various points later in the analysis when it was argued by the respondent that his choice about a wetland would not be altered by the values of those features, unless, of course, two wetlands were otherwise identical. The resulting feature set is shown in Figure 2.

Establishing Conditional Value Functions

The third stage of the process is establishing the conditional value functions. At this stage the differences between the Rigourous and the Edwards approaches begins. In the Edwards approach, the respondent was asked to identify maximum and minimum plausible (as opposed to possible) levels for each feature. These were used to create a graph as shown in Figure 3. The respondent was then asked to draw a curve which represented his feelings about the relative value of different levels of the feature. In this study, as with those reported by Edwards (1977), these curves were essentially linear, or were composed of linear segments. As noted earlier, two features (interspersion of wetlands within the landscape, and the replacability of a wetland) had been assigned measures that were not intuitively clear. No transformation from feature level to value could be obtained, so with no conditional value function, the features were discarded. The respondent and a colleague expressed a willingness to give up some theoretical precision to obtain a scheme that would be workable and understandable.

The Rigourous approach also asked for maximum and minimum plausible values. The respondent was then asked to identify a mid-value point for the feature. The mid-value point of any two feature levels is the level of the feature where the respondent would be as happy to have an increase from the lower valued feature level to the mid-value point as to have an increase from the mid-value point to the higher valued level. The mid-value point is assigned a value half way between the values assigned to the upper and lower valued points. Thus, if 1,000 hectares of wetland had a value of 1.0, and no wetland a value of 0.0, and 400 hectares was the mid-value (value of 0.5), then 400 hectares is as much more desirable than no wetland as 1,000 hectares is more preferred than 400 hectares of wetland. By beginning with the most preferred and least preferred feature levels, and repeatedly applying the mid-value concept to smaller and smaller intervals, a value function can, in theory, be developed. However, the respondent had great difficulty grasping the concept of equal-valued increases in the levels of a feature. In one case, he insisted on answers that were inconsistent, even when the inconsistency was demonstrated. Such behavior has been reported by other researchers and interpreted as reflecting both the complexity of the task, and the influence of initial conditions on preferences (Tversky, 1977). For features with discrete scales, such as interspersion type and site type, the respondent was unable or unwilling to define mid-values at all. The difficulties were so pervasive that this approach was abandoned as generally unworkable within the time available.

Ranking the Features

In the Edwards approach, ranking of the features may be done before or after the conditional value functions are defined because the two steps are independent. In the Rigourous approach, conditional value functions must be obtained first because they are necessary to obtain the rankings. Both approaches require that the features first be ordinally ranked. From there on the approaches diverge.

Edwards Ranking

Once the features have been ordinally ranked, the Edwards approach assigns an arbitrary weight to the least important feature (in this study, 10 was used). The respondent is then asked to specify how many times more important than this feature is the next more important feature. By continuing this process, a set of ratio-preserving weights for the features is obtained. Cross checks were made to ensure consistency. Where features were identified as elements in a hierarchy, the features within each hierarchic group were treated separately and then combined by repeating the procedure with the next higher hierarchic level. Over-all ratings were obtained by multiplying the weights of the group by the weights of the features within the group, each normalized to a zero-one scale. This process of hierarchic ranking reduces the cognitive strain and preserves the relative importance of the higher level values (in Figures 1 and 2, the values of ecological productivity/diversity, threat, and known use by birds.)

On the basis of these ratings, some features were deemed so insignificant, that a decision was unlikely to be determined by them. The three lowest rated features, with a combined contribution of less than 5% of the total were discarded. This process was a judgement call on the part of the decision maker and the importance ratings provided a guide, not a rule. The quality of the results from this process can only be tested against the intuitive sense of the decision maker, since it is his preferences which are being modelled. Any hesitance about the results of the analysis on the part of the decision maker is evidence that further work clarifying preferences is necessary. In this study, the initial results were accepted by the respondent, obviating the need for revisions. In this study, Edwards rankings were done before the conditional value functions, and so the value functions for the three discarded features were not developed, avoiding some work.

Rigourous Ranking

In the Rigourous approach, the issue of rank is a part of the aggregation process which begins with a consideration of the preferential independence of the features. This is done to identify features that may legitimately have their value added together, and so require ranking to know their relative contributions. Preferential independence can be described with the following example. Suppose two wetlands, each described by the same set of features, are compared, and are identical in all but two features. Then the preference between the two will depend on the feature levels of the two remaining features. A series of preferred choices between various levels of the two varying features can be identified. In addition, the features common to both wetlands (the complementary features) may take on a variety of levels. If the preferred choices do not change as the complementary features vary, then the two features are preferentially independent of the complementary set. (Preferential independence of a pair of features does not, however, imply the converse - that the remaining features are preferentially independent of the pair.) If two preferentially independent pairs of features have a common feature, then the three features can be described as mutually preferentially independent. If, and only if, mutual preferential independence holds, the conditional value functions of the three features can be added together to reflect the decision maker's preferences. As additional preferentially independent pairs are identified, additional overlaps may be found, increasing the number of mutually preferentially independent features. There may be more than one set of mutually preferentially independent features. Within each set, the features may be ranked and weights assigned, prior to summation of the conditional value functions. When a set of features is mutually preferentially independent, the sum of the weighted conditional value functions of the features in the set becomes one element in a more complex equation that will finally give a value index.[2]

In this study, six features were mutually preferentially independent, and so could be added together. The Rigourous approach to rating the importance of these features examines tradeoffs made between the physical levels of the features. The problem is to identify the level of a higher ranked feature that is equivalent in value to the best level of a low ranked feature. The conditional value function of the higher ranked feature can then be used to establish a ratio of importance between the two features.[3] By applying this procedure to each sequential pair of features, a set of importance ratios is obtained which can give the importance ratings for the additive features. However, in this study, the respondent could not determine tradeoffs he was comfortable with in three of five pairings. In each of the three, at least one feature was described by

---

[2] As an example, consider features a, b, c, d, e, f, g, and h, used to describe a wetland. If a, b, c, and d are shown to be mutually preferentially independent, then there is an expression

$$z = \lambda_1 v_1(a) + \lambda_2 v_2(b) + \lambda_3 v_3(c) + \lambda_4 v_4(d)$$

where λ's are the weights and v's are the conditional value functions, which gives the contribution of the four features to some scalar z. Then <u>all</u> features could be evaluated according to

$$V = j(a,b,c,d,e,f,g,h) = k(z,e,f,g,h,)$$

Furthermore, if it turned out that the features e, f, and g were also mutually preferentially independent, the V could be written as

$$V = l(z,y,h)$$

where

$$y = \lambda_5 v_5(e) + \lambda_6 v_6(f) + \lambda_7 v_7(g) \ .$$

[3] The approach uses the arbitrariness of value scales which by convention assigns the value of zero to the lowest level of feature i,

a discrete rather than a continuous scale. Thus, although preferential independence could be established, the Rigourous ranking approach was not workable within the time available.

Aggregation

The final stage in the decision analysis approach confronts the problem of aggregating the disparate values. In the Edwards approach, aggregation is, by definition, simply the addition of the weighted conditional value functions. Consequently, by definition, it works.

The Rigourous approach draws together the sets of additive features obtained in the preferential independence tests and the non-additive features. As noted above, in this study, six of nine features were shown to be additive. No combination of the remaining features

---

$v_i(x_i^0) = 0$, and the value of 1 to the highest level of feature i, $v_i(x_i^1) = 0^1$, where v_i is the conditional value function of feature i, normalized to a zero-one scale, and x_i^0 and x_i^1 are the lowest and highest levels of feature i respectively. Since the features in question can be added, and are independent of all other features, we can inquire about the level of x_i^* to make the decision maker indifferent between the pairs

$$(x_i^*, x_j^0) \sim (x_i^0, x_j^1)$$

This can be written in terms of values as

$$v_i(x_i^*) + v_j(x_j^0) = v_i(x_i^0) + v_j(x_j^1)$$

because of preferential independence and additivity. However, by cancelling out those elements assigned, by definition, a value of zero, what remains is

$$v_i(x_i^*) = v_j(x_j^1)$$

Thus the value of the best level of x_j (the lower ranked feature) can be expressed by $v_i(x_i^*)$, and the value of $v_i(x_i)$ becomes the multiplier of v_j to allow the correct addition.

(size of wetland, the uniqueness of the wetland, and threat to the wetland) was additive.

The tradeoffs between the three features were obtained using a "brute force" series of question. One feature at a time was held constant. The respondent was given a set of feature levels for the other two features, and, in another set asked to specify the level of one feature, given the level of the other, that would leave him indifferent between the two sets of features. By repeating the questions at three different levels spread over the plausible range of the constant feature, a series of pairs of indifference points were obtained. The questions were asked over two days. The second day's questions filled in gaps from the first day, questioned curious answers, and repeated some questions to check for consistency. The responses were consistent over the two days.

The series of pairs of indifferent points in three dimensions indicated the tradeoffs between the three features. A geometric abstraction of the tradeoffs was constructed (Figure 4). The abstraction was intuitive, but given the imprecision associated with any tradeoff answers, this seemed adequate. More importantly, when the qualitative nature of the results were explained to the respondent, they were considered to be representative of his preferences. An example of this qualitative result is that as threat to the wetland increased, uniqueness became increasingly important, relative to size. The abstraction was expressed mathematically to give a tradeoff index: a single number normalized from zero to one reflecting the relative preference for any combination of the three non-additive features. The mathematical expression, shown in Figure 4, shows the linear nature of the relationships.

The last stage of the Rigourous aggregation process was combining the sum of the additive features' conditional value functions with the tradeoff index from the non-additive features. A number of approaches were tried, however, most required choices of such complexity that they could not be dealt with effectively by the respondent. In the end, the respondent was presented with two hypothetical wetlands, and asked how many times more important one would be than the other for preservation. From this value, the relationship between the tradeoff index and the sum of the additive features could be determined. Time constraints prevented more choices from being presented, so the reliability of the answer to this single complex task was dubious. Consequently, results from variations of the scheme derived were also presented to reflect the uncertainty about the stated relative value of the two hypothetical wetlands. These results were applied to six wetlands in Southern Ontario with which the respondent was familiar.4/ The value indices for these wetlands were calculated, and, with the resulting rankings, were presented to

---

4/ The six wetlands were the National Wildlife Areas of Southern Ontario that contained large areas of wetlands: St. Clair, Long Point, Big Creek, Weller's Bay, Wye Marsh, and Mississippi Lake.

the respondent. He was asked to choose the set of ratings and ranks that best reflected his preferences. He had no hesitation in picking a variation of the derived scheme which simply multiplied the tradeoff index with the sum of the additive feature' weighted conditional value functions. The respondent's colleagues concurred with his choice.

Results

The effectiveness of the different approaches is shown in Table 1. With three sets of independent choices between the Edwards and Rigourous approaches, there are eight possible combinations. However, not all these combinations give results. The intractibility of the mid-value approach to obtaining conditional value functions (recorded in the second column) eliminates half of the eight possible combinations. Similarily, the lack of results from the Rigourous ranking procedure (third column) reduces the option by half again. Thus the two successful approaches both used the Edwards approach to obtain conditional value functions and rankings. The table shows that either approach to developing the aggregation will provide results.

What is left to consider is the relative effectiveness of the two successful approaches, one which assumes additivity of all features, and one which rejects that assumption and tests for the legitimacy of adding feature values. Table 2 shows the value indices and ranks of the six wetlands from the two successful approaches. The biggest difference is the switch in the rank of the St. Clair and Long Point wetlands. Further, the range of the indices associated with the Edwards approach to aggregation is less than when additivity is not assumed. The respondent clearly preferred the ranking and the range of indices resulting when additivity is not assumed. This chosen scheme will be referred to as a modified Edwards approach.

As sensitivity analysis of the chosen scheme showed a tremendous stability of the results to variations of the weights of the various additive features. Table 3 shows the weights developed for the additive features, and their maximum and minimum values, when varied individually, without producing a change in rank. Weights could be as low as 0.008 without inducing any change in ranking. For five of the six features, the weights could go to zero. Weights could increase by at least 60% without inducing any rank change, and for all but one feature, could more than double. This insensitivity did not reflect a lack of discrimination by the evaluation scheme, but, turned out to be entirely predictable. The better wetlands tended to be better rated than inferior wetlands in almost all features. In an extreme case where a wetland is better or worse than others in all features, any set of positive weights will produce the same result. In the study, the closeness to the extreme case resulted in a general insensitivity to the weights.

CONCLUSIONS & DISCUSSION

Conclusions drawn from this study of a single application would have little importance if they were not supported by other empirical work and by a substantial body of theory.

The first inference is that the complexity of the Rigourous approaches within decision analysis are beyond the ordinary respondent's ability.[5/] This is particularly the case for mid-value approaches to conditional value functions and the Rigourous ranking procedure. The results support the work of Tversky (1977), Edwards (1977), Ulvila and Snider (1980), and others who express concern about the abilities of decision makers to deal effectively with conditional value functions, let alone value functions over several features. This study has been concerned with the form of decision analysis where outcomes are presumed to be known; outcomes which are known with uncertainty require an even more complex approach. Thus, it seems essential to the successful use of decision analysis to use simple approaches.

An example of the importance of simplicity was in the process of defining the preference structure for the non-additive features. An initial questioning approach was confusing to the respondent and difficult for the analyst. A computer algorithm could have been used (as suggested by Keeney and Raiffa (1976)), but would have reduced the analyst's sensitivity to the complexity of the task given to the respondent. A simple questioning procedure, consequently, offers advantages to both the analyst and the respondent.

[5/] With training or consultation over three to six months, Bell (1977), Smallwood and Morris (1980), and deNeufville and Keeney (1972), were able to help decision makers through the more complex Rigourous approaches with success. The difference is clearly in the time available: what is possible in twelve to twenty-five weeks is not possible in two or three weeks. The crucial benefits of the modified Edwards approach is an ability to meet the need for decisions quickly and relatively inexpensively.

The limitations of people affect the process in two ways besides any difficulties imposed by the complexity of the questioning. The first, closely related to the issue of complexity, is the concern for the consistency of the respondents' replies, which the literature suggests can be a problem. However, this is reasonably easily checked. Stretching the process over several days is likely to point up any inconsistencies. The respondent in this study showed evidence of substantial consistency over several of days.

The second, and more important issue, is the very real difference between people. These differences can highlight unclear features, but can also represent different political interests and personal values. A ranking of the features in this study by another CWS staff person had essentially no correlation ($r^2 = 0.0006$) with that of the prime respondent. Most of the differences could be attributed to different interpretations of the features (the second set of rankings was done by someone who had not gone through the process of identifying, and so clarifying understandings of, objectives and features), but some was clearly a different set of values.

As noted above, different ranking of the features may also reflect a discrepancy in the understanding of the purpose of the evaluation. Different purposes will result in evaluation schemes with different mathematical forms, reflecting the different values associated with differing purposes. For example, an evaluation scheme to screen several thousand wetlands for general quality level will be quite different from one to choose which of a few possible wetlands should be chosen to be covered by a highway. From this it is clear that the purpose of the evaluation must be very carefully defined. Similarly, features used in an evaluation scheme must be carefully and clearly defined. If different people have different concepts of what is being measured and why, as described above, they will inevitably associate different values with those features. Decision analysis offers some assistance to the process of defining purposes and features.

From this study, it is also clear that additivity can not be automatically assumed. This is supported by the suggestion of Einhorn and Hogarth (1975) that the mathematical form of the scheme is more important than the weights used in determining the aggregate value. This suggests that although Edwards is substantially correct in his insistence on simplicity, his assumption of additivity can lead to incorrect rankings. Thus, tests for preferential independence are a valuable step in the process of creating an evaluation scheme.

The insensitivity of the weights reflects findings by Einhorn and Hogarth (1975), Dawes and Corrigan (1974), and others that weights of features in an aggregation scheme are not tremendously important. Dawes and Corrigan (1974) showed that random weights could function as an effective discriminator in some cases. Choosing festures which correctly reflect the values to be considered is much more important. There are several reasons for this insensitivity. Natural environments, such as wetlands, are complex systems with highly interrelated features. They are unlikely to have most features rated very well and also have the remaining few rated very low. As noted earlier, this trending together is why the results of this study had such insensitivity to the weights used. Because the features do trend together, fewer features are needed to capture the quality of a wetland. And real data contains both sampling and measurement error which reduce the sensitivity of the analysis.

Since the issue of which features to include seems important, it is often thought that simply increasing the number of features is a way around that problem. However, if the features are independent, as more features are added, the evaluations will increasingly tend to a middle value because of the action of the Central Limit Theorum. Thus, increasing the number of independent features decreases the discrimination of the evaluation scheme. If the features are dependent, then only a few are needed to evaluate the wetland. Consequently, careful limiting of the number of features to be used is important. Edwards (1977) suggests between eight and fifteen features; Ozernoi and Gaft (1977) suggest about a dozen.

The decision analysis approach produces a scheme which reflects the respondents' particular views. The result is not definitive. Instead, it is particular to one individual in one agency at a given moment. As such the scheme presented in this study is unlikely to reflect the concerns of other people in other agencies. However, a decision scheme for a given purpose can be developed without undue difficulty. And the approach is inexpensive enough (five to ten hours per respondent, a week of professional time per respondent, and a week of professional time for bringing the results together) that it is a reasonable possibility for many agencies.

Decision analysis is apparently able to develop an evaluation scheme that matches the decision maker's preferences. However, there is evidence that there are equally important benefits which do not come from the scheme developed. Rather, they stem from the qualitative clarification of interests and preferences that results from the individual's participation in the process. Edwards (1977), and Ulvila and Snider (1980), have both reported how decision analysis in its simple forms has permitted much more effective negotiation. This has been because one or both sides were helped to see what was important to them and what was important in the interests of the others. By attention to those important issues, rather than negotiating about complete proposals with their unthought-about implications, more creative solutions are possible (Fisher and Ury, 1981). This negotiation advantage has been described in papers in the business management field (Bodily, 1981; Brown and Alley, 1982).

In the context of wetland evaluations, by permitting an agency to identify important issues it is in a stronger position to deal with other agencies with apparently conflicting objectives. Even the best evaluation scheme is useless if it can not be used because of inter-agency differences. If an agency knows which issues, or values are central to its interests, and can also acknowledge issues of importance to other agencies, a climate conducive to effective application of a wetland evaluation scheme may be obtained.

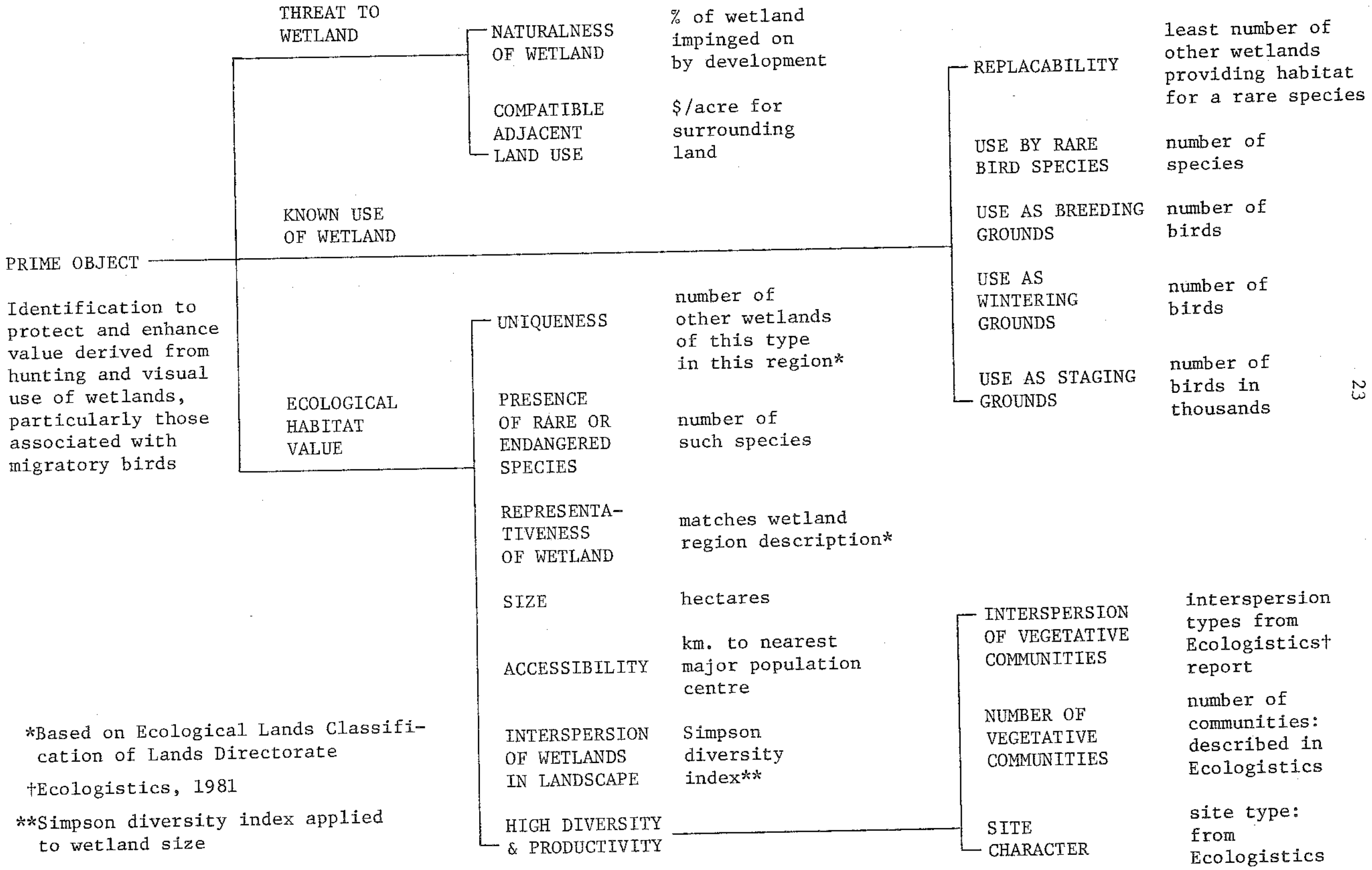
SUMMARY

Decision analysis is a set of tools which can help individuals or agencies clarify their preferences, and help them create evaluation schemes for natural environments. These schemes are both defensible because of their robustness, and inexpensive because of the insistence on a small number of clearly defined features. Consequently, the schemes can meet the needs of bureaucratic agencies.

A trial of the two possible approaches, Edwards, and Rigourous, showed that to obtain results within a limited time period, the procedures must be kept simple. However, the assumption of additivity advocated by Edwards to keep that simplicity gave misleading results. Consequently, while simple procedures are generally more useful, the use of preferential independence tests is necessary to check that additivity is a legitimate reflection of preferences.

The approach, using simple conditional value functions and ranking procedures, combined with preferential independence tests to determine the mathematical form of the evaluation scheme, is able to capture the preferences of a decision maker. There are cautions necessary because of the natural differences between people. However, the process of the approach can help resolve the differences of interests and values between individuals within an agency, and between the representatives of different agencies. The decision analysis process does this by highlighting important values and so facilitating negotiations. In the political world of allocating society's resources, and in this case, choosing wetlands to preserve, the decision analysis approach holds much promise.

Figure 1: Features and Objective Before Consideration of Conditional Value Functions or Aggregation

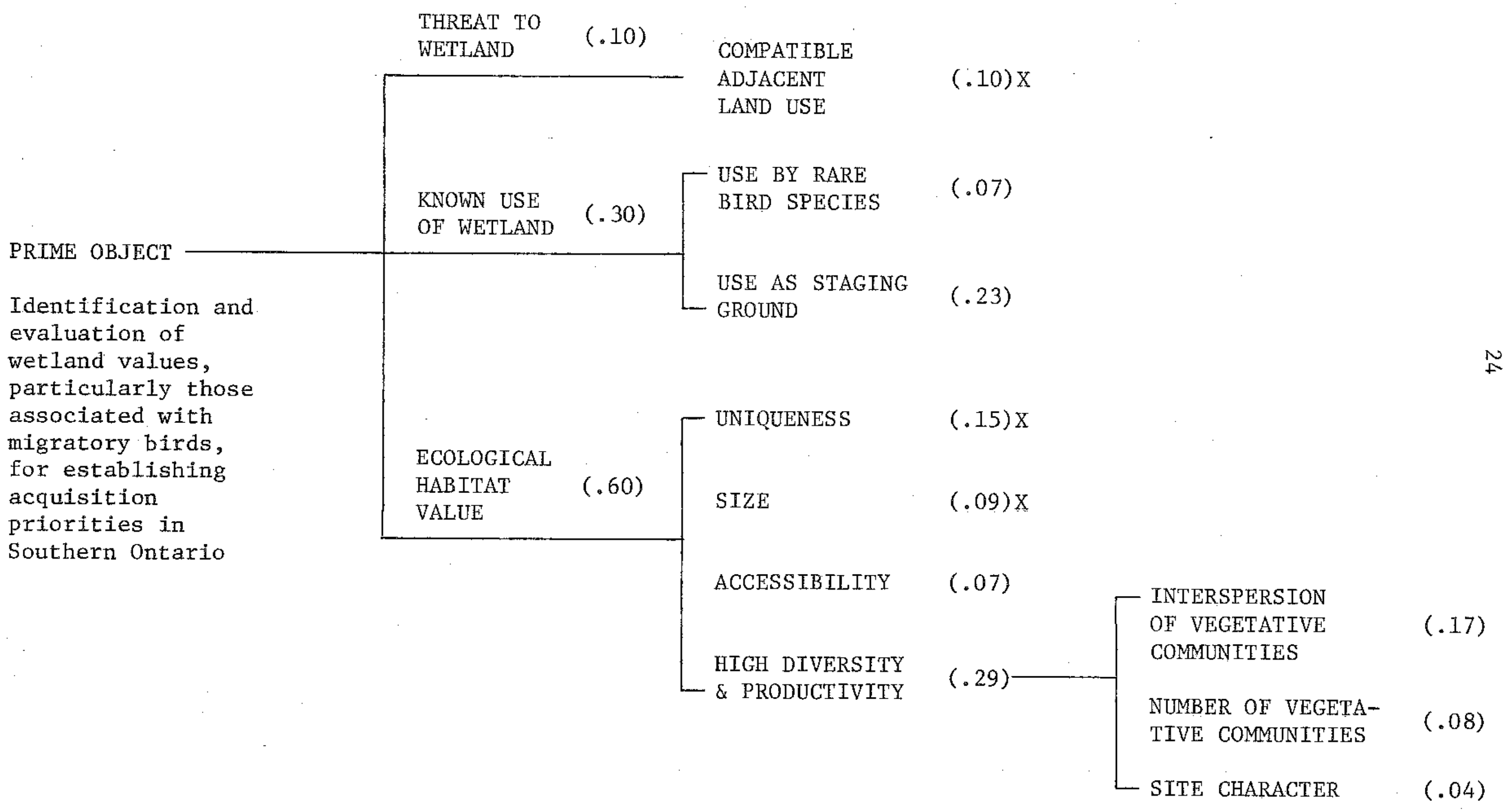


*Based on Ecological Lands Classification of Lands Directorate

†Ecologistics, 1981

**Simpson diversity index applied to wetland size

Figure 2: Final Feature Set and Weights for Features: Feature definitions are the same as in Figure 1, and features marked by an X were not found to be additive.



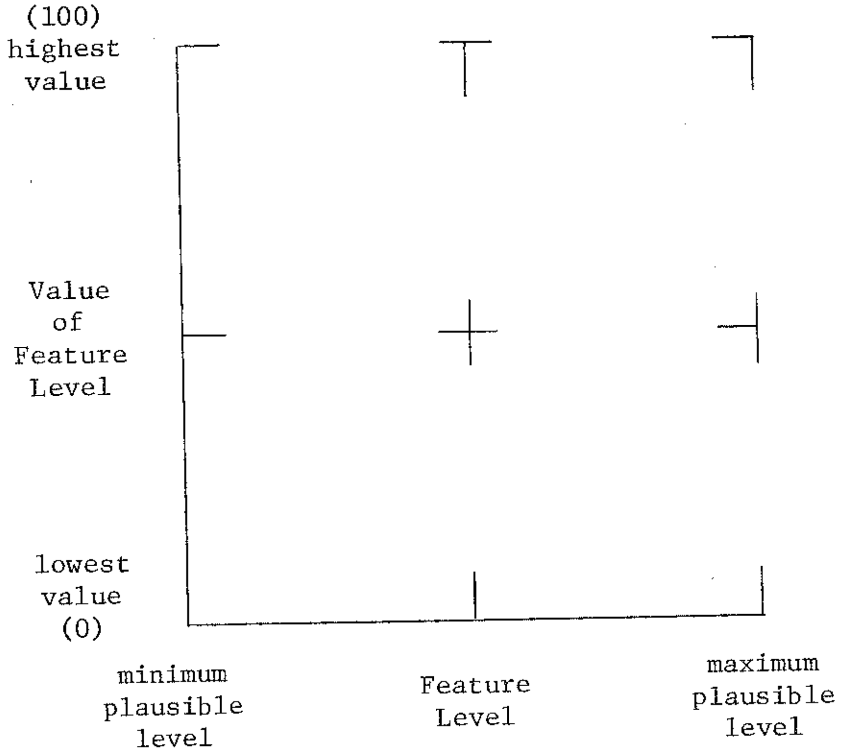


Figure 3: Empty Graph Presented to Respondent in Edwards Approach to Conditional Value Functions.

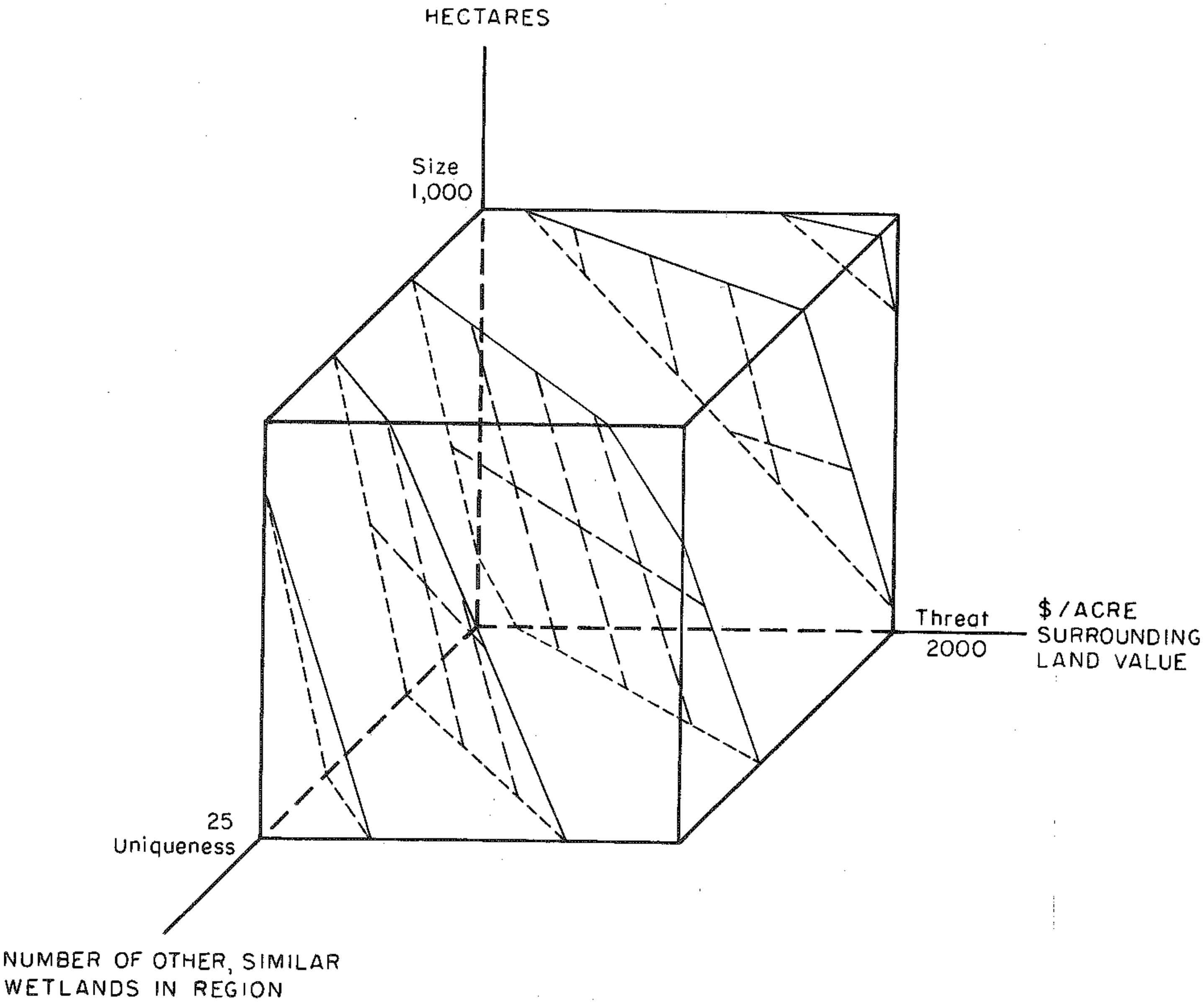


Figure 4: Three-Dimensional Abstraction of Responses

Abstraction is defined mathematically by the expression:

$$V_f = 1 - \frac{\dfrac{(u + 27.5 - h/80) \times (5200 - 4h/5)}{(t + 3{,}200 - 4h/5)} - 17.5 + h/400}{67.8125 + (5.208 \times h/100)}$$

where u is uniqueness, h is size, and t is threat.

Table 1: Results from Combinations of Three Independent Steps in Decision Analysis

Steps	Methods: Departure from Edwards Approach			
	Pure Edwards Approach	Mid-value Conditional Functions	Additivity not Assumed	Rigourous Rating of Added Features
1) Obtain Conditional Value Functions				
a) Edwards approach	X		X	X
b) Mid-value approach		0		
2) Develop Aggregation				
a) Additivity assumed	X	–		X
b) Additivity not assumed: preferential independence tested			X	
3) Weighting of features to be added				
a) Edwards approach	X	–	X	
b) Rigourous approach				0
Result obtained	YES	NO	YES	NO

Legend:
X step successful in sequence
0 step unsuccessful in sequence
– not attempted because of previous failure in sequence

Table 2: Results of Edwards and Modified Edwards Approaches Applied to Six Wetlands

	Edwards Additivity Assumed		Modified Edwards Additivity Not Assumed	
	Value Index	Rank	Value Index	Rank
St. Clair	.30	1	.67	2
Big Creek	.58	3	.41	3
Long Point	.79	2	.73	1
Wye Marsh	.21	5	.07	5
Wellers Bay	.31	4	.15	4
Mississippi Lake	.20	6	.03	6

Table 3: Ranges of Weights Without Rank Changes: Modified Edwards Analysis

Feature	Weight	Max. Weight	Min. Weight
Site Character	.07	.59	0
Number of Vegetative Communities	.13	∞	0
Interspersion	.26	5.95	.008
Accessibilities	.11	.96	0
Use as Staying Grounds	.33	.79	0
Use by Rare Bird Species	.10	.168	0

REFERENCES

Alley, H. R. 1983. The Use of Decision Analysis in the Selection of Wetland Evaluation Schemes." M.S. Thesis, Cornell University.

Bell, D. E. 1977. A Decision Analysis of Objectives for a Forest Pest Problem. In Conflicting Objectives in Decisions, pp. 389-421. Edited by D. E. Bell, R. L. Keeney, and H. Raiffa. Wiley-IIASA International Series on Applied Systems Analysis. John Wiley and Sons: Chichester.

Bodily, S. E. 1981. When Should You Go To Court: How a Company Can Use Decision Analysis to Achieve the Best Outcome - for Both Sides - in a Legal Dispute. Harv. Bus. Rev. 59(3):103-13.

Brown, D. J.M., and Alley, P. H.R. 1982. Management of Legal Disputes. In Corporate Law in the 80s, pp. 401-26. Special Lectures of the Law Society of Upper Canada, 1982. Richard DeBoo, Don Mills, Ontario.

Dawes, R. M., and Corrigan, B. 1974. Linear Models in Decision Making. Psychol. Bull. 81(1):95-106.

de Neufville, R., and Keeney, R. L. 1972. Use of Decision Analysis in Airport Development for Mexico City. In Analysis of Public Systems, pp. 497-519. Edited by A.W. Drake, R.L. Keeney, and P.M. Morse. Cambridge: M.I.T. Press.

Edwards, W. 1977. Use of Multiattribute Utility Measurement for Social Decision Making. In Conflicting Objectives in Decisions, pp. 247-76. Edited by D. E. Bell, R. L. Keeney, and H. Raiffa. Wiley-IIASA International Series on Applied Systems Analysis. Chichester: John Wiley and Sons.

Einhorn, H. J., and Hogarth, R. M. 1975. Unit Weighting Schemes of Decision Making. Organ. Behav. Hum. Perform. 13(2):171-92.

Fisher, R., and Ury, W. Getting to Yes: Negotiating Agreement Without Giving In. Boston: Houghton-Mifflin Co., 1981.

Keeney, R. L., and Raiffa, H. 1976. Decisions with Multiple Objectives: Preferences and Value Tradeoffs. Wiley Series in Probability and Mathematical Statistics. John Wiley and Sons: New York.

Ozernoi, V.M., and Gaft, M.G. 1977. Multicriterion Decision Problems. In Conflicting Objectives in Decisions, pp. 17-39. Edited by D. E. Bell, R. L. Keeney, and H. Raiffa. Wiley-IIASA International Series on Applied Systems Analysis. John Wiley and Sons: Chichester.

Smallwood, R. D., and Morris, P. A. 1980. A Task Force Decision Analysis. Ops. Res. 28(1):60-80.

Tversky, A. 1977. On the Elicitation of Preferences: Descriptive and Prescriptive Considerations. In Conflicting Objectives in Decisions, pp. 209022. Edited by D. E. Bell, R. L. Keeney, and H. Raiffa. Wiley-IIASA International Series on Applied Systems Analysis. John Wiley and Sons: Chichester.

Ulvila, J. W., and Snider, W. D. 1980. Negotiation of International Oil Tanker Standards: An Application of Multiattribute Value Theory. Ops. Res. 28(1):81-96.