THE AUSTRALIAN JOURNAL OF AGRICULTURAL ECONOMICS

VOL. 29 DECEMBER 1985 NO. 3

AN EXPERIMENT IN MULTIATTRIBUTE UTILITY THEORY*

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A version of multiattribute utility theory is evaluated as an aid to social decision making using an Australian case study. A multiattribute utility function is assessed over the descriptive, discrete decision alternatives of the decision problem rather than over the risky consequences of the attributes as in the standard approach. The evaluation is made first from the perspective of the decision analysts as a test of the feasibility of the method, and second, from the perspective of social decision makers as a test of the value of the analysis to them. Several difficulties arose in administering the procedure, and the decision makers were sceptical about the derived prescriptions. Nevertheless, the research findings appear to support the proposition that multiattribute utility theory should be viewed as more than merely a normative device for social decision making by experts.

This study was designed as a contribution toward testing the value of multiattribute utility theory as an aid to public decision making. The evaluation is based on a case-study application of an adaptation of the method to the apparent conflict of interest between pastoralists and tourists on pastoral lease land in the Flinders Ranges of South Australia.

In the standard version of multiattribute utility theory (Keeney and Raiffa 1976), the analyst seeks to elicit a multidimensional utility function over the relevant attributes of the consequences of the decision problem to permit a ranking of alternative choices. Attributes in this context represent yardsticks (or 'means') in terms of which achievement of specified social objectives can be quantified. The attraction of the method lies in its apparent ability to handle sets of attributes which can be either quantitative or qualitative or mixtures of the two. This characteristic seems to be of particular value for public decision analysis involving the often non-commensurate social objectives of economic efficiency, equity and environmental quality.

The specification of consequences, however, can be a very time-consuming and difficult, sometimes impossible, task. This is because of problems in specifying the appropriate set of attributes and how they are to be measured, and in fathoming the complex, obscure and uncertain relationships that often exist between decisions and their consequences. Specification of the required multidimensional probability distri-

* This research was funded by a Postgraduate Research Scholarship from CSIRO Division of Wildlife and Rangelands Research, Deniliquin, NSW.

butions for uncertain consequences is also likely to be a major source of difficulty.

The version that was developed and applied here overcomes these difficulties with the standard method. A multidimensional utility function was specified over the decision alternatives *per se*, rather than over the range of attribute outcomes. Because the decision involved simultaneous choice of several decision variables, treating each variable as an attribute reduced the process of specifying a multiattribute utility function to specification of preferences over the set of options. This approach, which appears not to have been described previously, simplifies preference elicitation, albeit with some disadvantages, which are discussed later. The adapted approach was extended to test the possibility of using multiattribute utility theory procedures to specify social welfare functions.

Decision analysis in general, and multiattribute decision theory in particular, is sometimes seen as a purely normative means of prescribing the optimal decision in some choice situation. However, the contribution of decision analytic approaches can be greater than this. The analysis can show how the decision maker might set about systematically identifying and structuring objectives, making value trade-offs, and balancing risks (Keeney and Raiffa 1976, p.1). It can also provide a vehicle for communicating ideas, information and judgments relevant to the decision problem among those involved in the decision process. For example, in a situation such as that described herein where numbers of people are affected by the decision reached, decision analysis can provide a structured format for the analyst to communicate information to the decision makers (and others) about the preferences of the affected parties.

It follows that the evaluation of the method attempted here should not be confined simply to the question of whether the prescriptions of the analysis were acceptable to the decision makers. Rather it is necessary to attempt the more difficult task of evaluating the extent to which the analysis contributed to the overall process of reaching a decision. Moreover, there are questions about the method itself which should be considered in any evaluation of it. The study provides some evidence, within the limits of a single case study, about the feasibility, reliability and research resource requirements of steps in the analysis, such as those steps requiring the elicitation of preferences for various kinds of outcomes from a number of categories of respondents.

The primary concern in the paper is not with the identification of a socially optimal decision for the particular land-use issue studied. Nor is any attempt made to provide a general review of multiattribute decision analysis *per se*, (see Tell 1976; Keeney and Raiffa 1976). Instead, the focus of the paper is on the experience gained in applying a particular form of multiattribute utility theory to a particular social choice problem. The questions addressed are 'Did it work?' and if so, 'Did it help?'.

In the next section of the paper the nature of the case-study problem is outlined and the decision framework used is formulated. This is followed by an outline of the analytical approach and of the particular methods used in the study. The results of the application are then presented as a basis for the evaluation of the practical usefulness of the technique from the point of view of both the respondents and the analysts. Some concluding comments complete the paper.

The Case-Study Decision Problem

The Flinders Ranges is one of the most popular tourist attractions of South Australia's inland arid zone. While tourism has helped local businesses, particularly service industries, it has created problems for many of the area's pastoralists through encroachments on leased grazing land. The public is currently entitled to enter, drive through and camp upon pastoral leased land without obtaining the lessee's permission (Interdepartmental Working Group 1981). The problems caused by this seemingly unfettered access have been outlined by Hutchings (1979).

Many pastoralists are now seeking amendments to the existing regulations and lease covenants which would give them greater control over tourist access. Such amendments, if adopted, may, however, lead to a curtailment of what tourists may recognise as a 'long-established right' of use (Interdepartmental Working Group 1981, p. 109).

The South Australian Government is facing a number of decision options in relation to this land-use issue. Five policy decision variables appear to be relevant: (a) extent of tourist access to pastoral tracks (x_1); (b) extent of permitted tourist camping access on pastoral lands (x_2); (c) extent of permitted tourist off-road vehicle access to pastoral lands (x_3); (d) degree of restrictions on grazing practices (x_4); and (e) degree of provision of facilities to service pastoralists and tourists (x_5). Delforce (1982) provides a discussion of the relevance of each decision variable to the case-study problem.

Four descriptive, discrete levels for each decision variable were initially formulated as actual decision choices faced by government. These are shown in Table 1. When this table was formulated it was believed, from the information then available, that the existing situation was level 1 for x_1, x_2 and x_3 and level 2 for x_4 and x_5. More recent advice from the decision makers involved in the study and from other South Australian Public Service personnel, however, implies that level 4 better represents the *status quo* for x_1 to x_3. This misinterpretation reflects the difficulty in determining the legal position relating to public access to pastoral leases (Interdepartmental Working Group 1981).

A decision on land use in the area will involve selecting some combination of the various levels shown in Table 1. Ten alternative combinations judged likely to be of interest to decision makers are given in Table 2. The task for the decision analyst is to find the combination among these alternatives which yields the maximum utility using an appropriate multiattribute utility function. As noted, however, in addition to such possible prescriptive use, multiattribure utility theory may yield other benefits. The specification of the explicit decision framework of Table 1 might help decision makers to think through the complex issues involved in making a policy choice. It might also aid the decision process by pinpointing differences in value judgments leading to disagreement on a policy choice.

TABLE 1

Decision Variables and Their Discrete Options

Decision variable/attribute (x_i)	Decision option/attribute level			
	$x_i = 1$	$x_i = 2$	$x_i = 3$	$x_i = 4$
Tourist access to pastoral tracks (x_1)	All tracks private, except throughroads which are open to the public. Permission from pastoralists required to drive on private tracks.	All tracks private, except throughroads and government-designated tracks to areas of major public interest.	All tracks open, except private tracks in the vicinity of station homesteads, outstations and shearing sheds.	Tourists can drive along all tracks, without permission from pastoralists.
Camping access to pastoral lands (x_2)	Camping restricted to: (i) national parks; (ii) 200 m from through-roads, but not within 1 km from homesteads and 500 m from man-made water supplies; and (iii) anywhere with specific permission from pastoralists.	Camping restricted to: (i) national parks; (ii) 200 m from through-roads and government-designated tracks, but not within 1 km from homesteads and 500 m from man-made water supplies; (iii) areas of major public interest; and (iv) anywhere with specific permission from pastoralists.	Tourists can camp anywhere, except 1 km from homesteads and 500 m from man-made water supplies.	Tourists can camp anywhere, without permission from pastoralists.
Off-road driving on pastoral lands (x_3)	Prohibited, except with specific permission from pastoralists.	Prohibited, except to any areas of major public interest where no tracks exist, or anywhere with specific permission from pastoralists.	Permitted in all environmentally suitable areas, except in limited areas adjacent to homesteads, outstations, and shearing sheds.	Permitted in all pastoral areas, without permission from pastoralists.

TABLE 1 (continued)

Decision variable/attribute (x_i)	Decision option/attribute level			
	$x_i = 1$	$x_i = 2$	$x_i = 3$	$x_i = 4$
Restrictions on grazing practices (x_4)	All areas currently not included in national parks grazed without restriction (including areas of major public interest).	All areas currently not in national parks grazed to varying degrees under government guidelines to protect the pastoral productivity of the land.	All areas currently not in national parks grazed to varying degrees under government guidelines to protect all interests (tourism, pastoralism and environmental conservation).	Remove grazing from all areas of major public interest and designate as national parks. Limit grazing in other areas to that which is compatible with tourist use and conservation needs.
Provision of facilities (x_5)	Extend power supplies, and road and telephone networks servicing pastoral lands. Maintenance of existing tourist facilities to be undertaken only in existing national parks and towns.	Maintain existing facilities servicing both pastoralists and tourists. No extension or improvement to any existing facilities.	Provide more tourist facilities in existing national parks and in a few areas of major public interest on pastoral lands. Maintenance of existing tourist facilities receives highest priority.	Provide abundant tourist facilities throughout existing national parks and all areas of major public interest on pastoral lands. Permit facilities servicing pastoral lands to run down.

TABLE 2

Alternative Policy Combinations of Options for the Flinders Ranges

Decision variable/attribute	Combination[a]									
	I	II	III	IV	V	VI	VII	VIII	IX	X
Access to pastoral tracks (x_1)	1	2	2	3	2	2	2	2	2	1
Camping access to pastoral lands (x_2)	1	1	1	2	2	2	2	2	2	1
Off-road vehicle access to pastoral lands (x_3)	1	1	1	2	2	2	2	1	1	1
Restrictions on grazing practices (x_4)	2	2	2	3	3	3	3	3	3	3
Provision of facilities (x_5)	2	1	3	3	3	2	1	3	1	3

[a] Numbers represent the relevant option of the particular attribute for the combination in question. Thus, for combination I, $x_1 = x_2 = x_3 = 1$ and $x_4 = x_5 = 2$.

Research Methods

Decision analytic approach

Politically, the ultimate decision makers for this land-use issue (after Parliament itself) are the South Australian Ministers for Lands and for Environment and Planning. As lengthy interviews with the Ministers were impractical, proxy decision makers were chosen. These were senior executives in the South Australian Public Service whose recommendations could be presumed to influence the relevant Ministers strongly.

Multiattribute functions were elicited for these 'decision makers'. The respondents were encouraged to make these 'own preference functions' capture their professional or expert attitudes rather than merely their individual views. A 'social welfare function' was also obtained for each decision maker. For this purpose, pastoralists and tourists were assumed to be the only significant groups in society with an interest in the policy choice. This was a necessary simplifying assumption for the purpose of the research although, in reality, the interests of other groups such as conservationists and scientists may also be important.

Relevant cardinal, non-absolute preferences of small samples of four pastoralists and seven tourists were elicited to provide the basis for specifying the social welfare functions. The exact method is detailed later. Elicitation of the preferences of individual users of the study area also proved useful in pinpointing the conflicts of user preferences. Tests of the representativeness of the sampled pastoralists for the entire population of pastoralists and of the sampled tourists for a large sample of tourists are detailed in Delforce, Sinden and Young (1984). The interviews of the pastoralists and tourists were conducted in September and October 1981 and those of the decision makers in March 1982.

Standard version of multiattribute utility theory

The value of a particular combination of attribute levels to an individual can be measured as the total utility that person gains from the combination. Under the assumptions of mutual preferential independence and mutual utility independence amongst attributes, it follows from the axioms of von Neumann–Morgenstern expected utility (von Neumann and Morgenstern 1947) that the total utility function for a combination of n attributes may be decomposed into single attribute utility functions as follows:

$$U(x_1, x_2, \ldots, x_n) = f[U_1(x_1), U_2(x_2), \ldots, U_n(x_n)] \tag{1}$$

where $U_i(x_i)$ is a utility function over the range of possible levels of the ith attribute and depends only on the level of that attribute, x_i. Definitions of preferential independence and utility independence, and practical tests of the validity of these assumptions are given by Keeney and Raiffa (1976) and are discussed in the context of this study by Delforce (1982).

Where there is uncertainty about the consequences of each decision option, subjective probability distributions of the consequences are needed. Choices are then evaluated using the criterion of expected utility.

If $U(.)$ and $U_i(.)$ for all i are scaled from zero to one, the utility function of equation (1) may take either the additive form:

$$U(x_1, x_2, \ldots, x_n) = \Sigma_i k_i U_i(x_i) \tag{2}$$

or the multiplicative form:

$$U(x_1, x_2, \ldots, x_n) = \Pi_i\{[Kk_iU_i(x_i) + 1] - 1\}/K \tag{3}$$

where k_i is a scaling constant between zero and one for $U_i(x_i)$, and K is another scaling constant. For internal consistency in scaling, the magnitudes of the k_i values determine the value of K and hence the appropriate form of the function f in equation (1). If $\Sigma k_i = 1$, then $K = 0$ and f takes the additive form of equation (2). If $\Sigma k_i \neq 1$, then $K \neq 0$ and f takes the multiplicative form of equation (3).

The interpretation of the scaling constants k_i is rather obscure. For instance, Keeney and Raiffa (1976, pp. 271–3) provide a simple proof that the k_i values do not indicate the relative importance of their respective attributes. Hence, in policy analyses, care must be taken to avoid misinterpreting the k_i values.

Well-established procedures exist for the elicitation of single attribute utility functions $U_i(x_i)$ and the scaling constants k_i and K. Examples of the use of the standard version of the method are cited in Delforce (1982).

Adapted version of multiattribute utility theory

Initially in this study it was intended to follow the standard version of multiattribute utility theory of Keeney and Raiffa (1976). This involved trying to specify social objectives for the management of the Flinders Ranges, continuous quantitative attributes on which to measure consequences in terms of these objectives, and the levels of these attributes for each decision alternative. It also appeared to require an analysis of risk — that is, specification of probabilities over the consequences.

Considerable difficulty, however, was experienced in these attempts. The attributes of the consequences of alternative policy options relevant to assessing social preferences were not at all apparent and, more seriously, there were no readily establishable relationships between the policy options and the level of any such attributes of consequences. It seemed that a model structured in the conventional manner would have been too complex to be useful, if it could have been built at all. Certainly, it appeared unlikely that it would have achieved the supposed advantage of decision analysis of laying bare and clarifying the embedded preference and probability judgments.

A solution to this problem was found by specifying multiattribute utility functions over the descriptive, discrete levels of the decision variables shown in Table 1, *per se*. In other words, the decision variables were treated directly as attributes for purposes of utility elicitation.

With the decision model thus defined, the single attribute utility functions obtained were non-continuous functions. The procedure involved having each subject firstly assign a cardinal, non-absolute utility to the levels (options) of each attribute (decision variable) shown in Table 1. This was done for the pastoralists, tourists and decision makers, with the decision makers' preferences representing their professional ones.

Keeney and Wood (1977) have described a method using an index to measure a qualitative attribute on an interval scale. Experts are asked to assign a value to each attribute outcome on the appropriate scale, and a set of continuous, single attribute functions for the index values are elicited. It is unclear, however, how respondents could be encouraged to evaluate consistently a number of such indices that they would be likely to regard as being arbitrarily scaled. Chiefly for this reason, and also because the extra degree of complexity seemed unwarranted, this method was not used here. The advantage of greater simplicity of the procedure adopted was, however, bought at some cost. In particular, only weak checks of the validity of the assumptions of mutual preferential and utility independence between attributes were possible with just a few descriptive, discrete options for each attribute (see Delforce 1982). This is a weakness of the particular method which occurs because of the small number of options specified. One way of providing for stronger tests would have been to have specified additional levels for each attribute intermediate between those in Table 1. Again, however, the implied extra complexity seemed unwarranted.

In the absence of any sound validation procedure, the attributes (and their levels) were specified so that they appeared to be mutually preferential and utility independent, and it was then assumed that the conditions were adequately satisfied. This would probably have been unsatisfactory if the results of the study were to have been used for concrete policy recommendations because of the importance of these assumptions in justifying the use of multiattribute utility theory procedures. Nevertheless, it seemed reasonable for the expressed study purpose of illustrating and testing the practical usefulness of the approach.

The use of descriptive, non-continuous attribute levels also makes consistency checks of the elicited single attribute utility functions infeasible. Consistency checks suggested by Keeney and Raiffa (1976, pp. 198–200) and Anderson, Dillon and Hardaker (1977, pp. 71–3) require continuous quantitative attribute levels. Such checks are used to try to ensure that the subject is responding in a manner consistent with his or her inner preferences.

The need to elicit respondents' subjective probability distributions for risky consequences in the standard version of the procedure becomes superfluous in the adapted method since each respondent is assumed to balance mentally all the outcomes with their associated risks. This simplification, however, has the disadvantage that no explicit analysis of risk can be undertaken if desired. For example, decision makers may vary in their preferences for decision options only because they have different perceptions of the risks of the consequences of those options. If risk had been accounted for explicitly, analysis of the reasons for differences in perceived risks among decision makers, followed by exchange of information, might have helped the respondents to reach closer agreement. In cases where the issues mainly concern conflicts in beliefs (subjective probabilities), rather than in values (utilities), an explicit analysis of risk would be desirable.

Elicitation of non-continuous, single attribute preference functions

The use of descriptive, discrete levels for the attributes means that the von Neumann and Morgenstern (1947) utility game had to be used to elicit cardinal preferences for the attributes for all respondents. Cardinal utility values were assigned to each level of attribute i by having each respondent choose between the lottery, L, and the certain event, C:

$$(4) \qquad L: \begin{cases} p & (x_i^*) \\ 1-p & (x_i^\circ) \end{cases} \qquad\qquad C: (\bar{x}_i)$$

where x_i^* is the most preferred level for attribute i and has a probability p of occurrence; x_i° is the least preferred level for that attribute with a probability $1-p$; $\bar{x}_i$ is a certain level for attribute i such that x_i^* is preferred to $\bar{x}_i$ which is preferred to x_i°; and $U_i(x_i^*) = 1$, $U_i(x_i^\circ) = 0$. The probability p was varied until the subject was indifferent between L and C. At indifference, the expected utilities of L and C are equal, and $U_i(\bar{x}_i) = p$.

Elicitation of multiattribute scaling constants

To elicit values of the scaling constant, k_1, the respondents were asked to choose between the lottery, L^1, and the certain event, C^1:

$$(5) \qquad L^1: \begin{cases} p & (x_1^*, x_2^*, x_3^*, x_4^* \; x_5^*) \\ 1-p & (x_1^\circ, x_2^\circ, x_3^\circ, x_4^\circ, x_5^\circ) \end{cases} \qquad\qquad C^1: (x_1^*, x_2^\circ, x_3^\circ, x_4^\circ, x_5^\circ)$$

where $U(x_1^*, x_2^*, x_3^*, x_4^*, x_5^*) = 1$ and $U(x_1^o, x_2^o, x_3^o, x_4^o, x_5^o) = 0$. At indifference, $k_1 = p$. A similar procedure was used to elicit the values of all five scaling constants. These values were then used to derive for each respondent the appropriate value of K and hence the functional form of the multiattribute function for that person.

By these methods, multiattribute utility functions for the attribute levels in Table 1 were elicited for the samples of pastoralists and tourists as well as for the two decision makers.

Elicitation of decision makers' social welfare functions

Arrow (1963) proved that in general there is no procedure for deriving a group ordering of alternatives from the ordinal rankings of the alternatives of the individual members of that group that is consistent with five 'reasonable' assumptions. On the other hand, Fleming (1952, 1957) and Harsanyi (1955) were the first to provide sets of conditions under which a cardinal social welfare function might be specified as the sum of cardinal utility functions of individuals of a society (such as pastoralists and tourists). These 'conditions', however, restrict the relevant social welfare function to only a few special forms.

Keeney and Kirkwood (1975), Keeney and Raiffa (1976) and Keeney (1977) show that a less restrictive, arithmetic social welfare function is possible for cardinal utilities with an altruistic decision maker using a modification of multiattribute utility theory. An altruistic decision maker is one who wishes to incorporate the preferences of all affected parties into his or her own preferences and hence into his or her choice. Following this approach, the relevant social welfare function is the decision maker's altruistic preference function. The method involves having the decision maker scale preference functions for the different individuals to obtain a societal preference function. It is assumed that the decision maker's preference function for satisfying individual h is h's own preference function. That is, the individuals' assessed preference functions become attributes for assessing the decision maker's multiattribute social welfare function. Thus, for example, the social welfare function, W, for satisfying individuals A and B is:

$$W = W(U_A, U_B; d_A, d_B) \quad (6)$$

where U_A and U_B are the utility functions of individuals A and B, respectively, and d_A and d_B are the relevant scaling constants for U_A and U_B, respectively. The usual assumptions of mutual preferential and utility independence between U_A and U_B must be made in order to structure W. This general procedure, modified to incorporate descriptive, discrete attribute levels, was used in this study.

The approach unquestionably involves interpersonal comparison of utility. The use of such comparisons is a contentious issue and there seems little prospect that their validity can be confirmed or contradicted.

Strong normative assumptions underlie the altruistic welfare functions, as outlined in Keeney and Raiffa (1976, pp. 516–20). The validity and implications of these assumptions were not at issue in this research. Rather, once more, the concern was with providing a test of the usefulness of the approach in decision making by experts.

A three-step procedure was followed. In step 1, group utility functions for each attribute were determined separately from the two decision makers in respect of the g pastoralists and t tourists who were successfully interviewed earlier in the study. These (non-continuous) functions were determined as follows for the group of pastoralists or graziers (G):

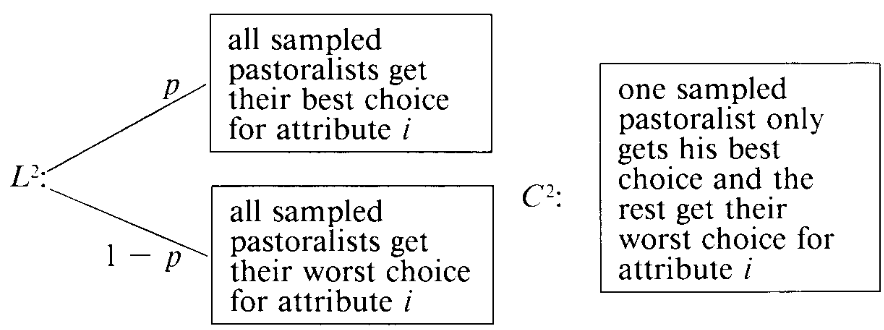
(7) $$U_G(x_i) = \Sigma_q G_q U_q^G(x_i) \text{ or } \Pi_q\{[G G_q U_q^G(x_i) + 1] - 1\}/G$$

where x_i measures the level of attribute i; G_q is the relevant scaling constant for $U_q^G(x_i)$, the utility of x_i to pastoralist $q(q = 1, 2, \ldots, g)$; and G is another scaling constant. Similarly for tourists (T):

(8) $$U_T(x_i) = \Sigma_r T_r U_r^T(x_i) \text{ or } \Pi_r\{[T T_r U_r^T(x_i) + 1] - 1\}/T$$

where $(r = 1, 2, \ldots, t)$. These functions give comparative utility values for the levels of each attribute in Table 1 for pastoralists as a group and tourists as a group, respectively.

The identities of the pastoralists and tourists were not disclosed to the decision makers. Thus, it could reasonably be assumed that the scaling constants would be the same for all members of each group for each decision maker. That is, $G_1 = G_2 = \ldots = G_g$ and $T_1 = T_2 = \ldots = T_t$. As a consequence, only one scaling constant needed to be elicited for each attribute for each user group and each decision maker. For example, with pastoralists this was done by having the respondents choose between the lottery, L^2, and the certain event, C^2, for each attribute in turn:

(9) 

with U (all their best choice) = 1 and U (all their worst choice) = 0. At indifference between L^2 and C^2, $G_1 = G_2 = \ldots = G_g = p$. Similarly for tourists, with the appropriate L^2 and C^2, $T_1 = T_2 = \ldots = T_t = p$.

In step 2, group utility functions across all attributes were elicited from the decision makers for the pastoralists and the tourists as separate groups. To structure these functions, U_G and U_T, it was necessary to have the decision makers specify scaling constants, g_i and t_i for the i single attribute utility functions, $U_G(x_i)$ and $U_T(x_i)$, respectively. Thus:

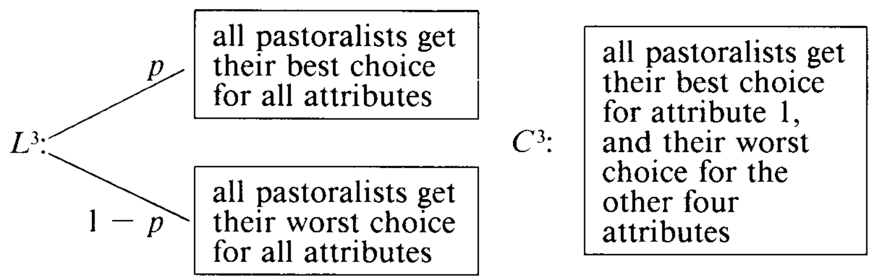
(10) $$U_G = \Sigma_i g_i U_G(x_i) \text{ or } \Pi_i\{[g' g_i U_G(x_i) + 1] - 1\}/g'$$

and

(11) $$U_T = \Sigma_i t_i U_T(x_i) \text{ or } \Pi\{[t' t_i U_T(x_i) + 1] - 1\}/t'$$

where g' and t' are the relevant residual multiplicative scaling constants. These functions give comparative utility values for the various combinations of attribute levels, such as those of Table 2, for pastoralists as a group and tourists as a group, respectively.

The procedure for calculating g_1 (the relevant scaling constant of $U_G(x_1)$) was to have each respondent choose between the lottery, L^3, and the certain event, C^3:

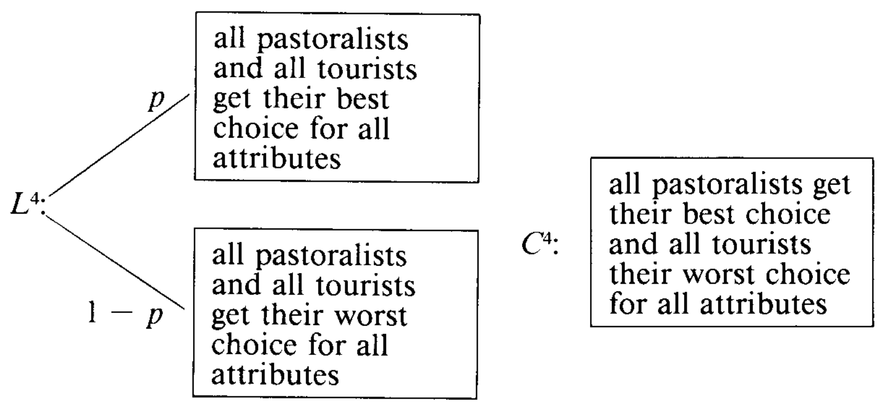
(12) 

At indifference between L^3 and C^3, $g_1 = p$ as before. This was then repeated for g_2 to g_5, and a similar procedure was used to specify t_1 to t_5.

A social welfare function (W) was specified in step 3 as follows:

$$(13) \qquad W = d_G U_G + d_T U_T \text{ or } [(Dd_G U_G + 1)(Dd_T U_T + 1) - 1]/D$$

where d_G is the scaling constant for U_G; d_T is the scaling constant for U_T; and D is a residual scaling constant. The scaling constants were determined for each decision maker as follows for d_G:

(14) 

At indifference, $d_G = p$, and similarly for d_T.

Elicitation was assisted by pointing out to the decision makers that anything in the lotteries (9), (12) and (14) could be implemented in practice by dividing the study area into sections within each of which a different set of land-use options from Table 1 could be applied. As shown below, it was found that there was considerable variety in the preferences of individuals of the same user group as well as between user groups. Therefore, it is hypothetically possible that a decision maker could make policy choices for different parts of the study area which would result in all individuals in a particular group receiving their worst (or their best) choices, as suggested in L^2, L^3 and L^4. The fact that in reality this hypothetical situation may be unattainable given the actual preferences of the pastoralists and tourists is irrelevant since, at this stage of the analysis, these preferences had not been disclosed to the decision makers.

Results of the Case Study

The first interview, conducted with a pastoralist, indicated a necessity to delete level 4 for all attributes. The reasons for this are detailed by Delforce, Sinden and Young (1984).[1] Thus, all results relate to only the first three levels in all cases. Actual results, in terms of elicited functions, are presented by Delforce (1982) who also draws out the implications for the land-use issues studied. Only those features of the results relevant to the present purpose are presented here.

The rankings of the first three options in Table 1 for the five attributes of the four pastoralists and seven tourists are shown in Tables 3 and 4, respectively.[2]

TABLE 3

Pastoralists' Rankings of the Options of Land Use[a]

		Pastoralist			
Decision variable/attribute	Option	G_1	G_2	G_3	G_4
Access to pastoral tracks (x_1)	1	1	1	2	2
	2	2	2	1	1
	3	3	3	3	3
Camping access to pastoral lands (x_2)	1	1	2	1	2
	2	2	1	2	1
	3	3	3	3	3
Off-road vehicle access to pastoral lands (x_3)	1	1	1	1	1
	2	2	2	2	2
	3	3	3	3	3
Restrictions on grazing practices (x_4)	1	2	1	2	3
	2	1	2	1	1
	3	3	3	3	2
Provision of facilities (x_5)	1	1	1	2	1
	2	2	2	3	3
	3	3	3	1	2

[a] A ranking of '1' means that the particular option is most preferred, and a ranking of '3' means that the particular option is least preferred. Thus, for example, $x_1 = 1$ is most preferred and $x_1 = 3$ least preferred by pastoralists G_1 and G_2.

[1] The decision to delete the fourth options is generally supported *ex post* by the findings of Delforce, Sinden and Young (1984). They obtained ordinal rankings of the four options of each decision variable shown in Table 1 from a sample of 97 tourist groups in the study area. The fourth options were ranked first for the most important decision variables 1, 2 and 3 by only 3 per cent or less of respondents, while they were ranked last by 83 per cent or more of them. In other words, tourists as a whole do not want option 4 anyway, although it would appear to be there for their taking if one accepts option 4 as the *status quo*. Unfortunately, its omission in the elicited preference functions means that the existing situation was not included in the utility analysis.

[2] Unsuccessful attempts were made with two other pastoralists. These attempts failed because the particular respondents found the von Neumann–Morgenstern game difficult to understand or refused to consider any options other than their most preferred ones.

TABLE 4

Tourists' Rankings of the Options of Land Use[a]

Decision variable/attribute	Option	Tourist T_1	T_2	T_3	T_4	T_5	T_6	T_7
Access to pastoral tracks (x_1)	1	2	1	1	2	3	2	3
	2	3	3	3	3	2	1	2
	3	1	2	2	1	1	3	1
Camping access to pastoral lands (x_2)	1	2	3	1	3	2	2	3
	2	1	2	2	1	1	1	1
	3	3	1	3	2	3	3	2
Off-road vehicle access to pastoral lands (x_3)	1	1	3	1	3	1	2	3
	2	2	2	2	1	2	1	2
	3	3	1	3	2	3	3	1
Restrictions on grazing practices (x_4)	1	3	3	3	3	3	3	3
	2	2	2	2	2	2	2	2
	3	1	1	1	1	1	1	1
Provision of facilities (x_5)	1	3	2	3	3	2	3	3
	2	1	3	1	2	1	1	1
	3	2	1	2	1	3	2	2

[a] See footnote to Table 3.

For these small samples there is a general lack of agreement in preferences both between pastoralists and tourists, and between individuals of the same user group. Delforce, Sinden and Young (1984) have investigated the degrees of concordance in ordering the options between larger samples of 33 pastoralists (out of the total population of 36 pastoralists) and 97 tourist groups and the corresponding multiattribute utility theory respondents. The preferences of the respondents for whom utilities were elicited are shown to be reasonably representative of the respective larger samples and hence of the corresponding populations.

The responses of tourists 1 to 4 in ranking the options of the first decision variable may seen unreasonable. They either preferred option 3 and ranked option 1 second (before option 2), or *vice versa*, which might be interpreted as inconsistent. However, all four respondents stated that, after giving first place to what they saw as the best option for one group, they felt it only fair to give second place to what they judged to be the best option for the other group.

The small numbers of multiattribute utility theory respondents interviewed reflected the high cost of data collection — having 97 tourists and 33 pastoralists ordinarily rank the options was feasible — having each of them undertake a two-hour interview for utility elicitation was not.

The rankings of the options for the two policy decision makers, DM_1 and DM_2, for their own utility functions, are displayed in Table 5.

TABLE 5

Decision Makers' Rankings of the Options of Land Use[a]

Decision variable/attribute	Option	Decision maker DM_1	Decision maker DM_2
Access to pastoral tracks (x_1)	1	3	2
	2	1	1
	3	2	3
Camping access to pastoral lands (x_2)	1	2	2
	2	1	1
	3	3	3
Off-road vehicle access to pastoral lands (x_3)	1	1	2
	2	2	1
	3	3	3
Restrictions on grazing practices (x_4)	1	3	3
	2	2	2
	3	1	1
Provision of facilities (x_5)	1	2	3
	2	3	2
	3	1	1

[a] See footnote to Table 3.

The implied rankings of the combinations of Table 2 using the decision makers' own preference functions are given in Table 6. As shown by Delforce (1982), a complete ordering for DM_2 was possible only when total utilities were calculated to six decimal places, compared with four decimal places for DM_1. However, no significance can be attached to the small differences in utilities for different combinations of options because of the non-absolute nature of the utility values. The

TABLE 6

Rankings of Policy Combinations Using Decision Makers' Own Preference Functions[a]

Rank	Decision maker DM_1	Decision maker DM_2
1	VIII	V
2	IX	VI
3	V	VII
4	VI	VIII
5	VII	IX
6	X	X
7	IV	IV
8	III	III
9	II	II
10	I	I

[a] See Table 2 for definitions of the combinations.

multiplicative functional form (equation (3)), which was found to be appropriate for both decision makers (as well as for the four pastoralists and seven tourists), seems vulnerable to such small differences. That is, the results were nearly always total utilities discernible only with a large number of decimal places. Nevertheless, the combination identified as most preferred for DM_2, for example, was confirmed as the best by the fact that it contained all his most preferred options.

The implied rankings of combinations by the altruistic social welfare functions elicited for the two decision makers are displayed in Table 7. The orderings are once more those for total utilities calculated to six decimal places. The differences in rankings between the two welfare functions reflect differences in the magnitudes of the various altruistic scaling constants elicited from the decision makers. As indicated earlier, nothing can be said about the policy implications of the underlying structures of the two functions.

TABLE 7

Rankings of Policy Combinations Using the Social Welfare Functions[a]

	Decision maker	
Rank	DM_1	DM_2
1	IV	X
2	V, VI	VI
3	–	IV
4	VII	V
5	VIII	I
6	X	VIII
7	I	III
8	IX	VII
9	III	IX
10	II	II

[a] See Table 2 for definitions of the combinations.

A different ordering of combinations, and therefore of options, occurred for both decision makers using their own preference functions compared with their social welfare functions – combination VIII (own) was most preferred compared with IV (altruistic) for DM_1 and combination V (own) compared with X (altruistic) for DM_2.

It is not surprising that the two types of functions produced discordant rankings of combinations because they were constructed using quite different methods. The own preference functions were elicited to capture the respondents' professional (or official) preferences. It may be supposed that, in formulating these preferences, they will have given some weight to the preferences of pastoralists and tourists as they perceived them. The preferences of users in the two groups actually elicited were not, however, disclosed to the decision makers at that stage. In contrast, the social welfare functions were obtained by mathematical aggregations of the actually expressed preferences of pastoralists and tourists. Consequently, unless the decision makers' original perceptions of the views of the two user groups were accurate, it is unlikely that the two functions would have yielded identical orderings of combinations.

An Evaluation of the Practical Usefulness of the Approach

Lessons for the decision analysts

Several difficulties arose as a result of the decision to assess the multiattribute utility functions directly over the descriptive, discrete decision options, *per se*. A particular set of problems also arose because this necessitated the use of the von Neumann–Morgenstern game.

First, the decision to consider only a fixed set of policy options meant that additional options between, or more extreme than, the fixed set could not be ranked if they appeared to be of relevance once the first interview had commenced or during the subsequent analytical stage. By contrast, using the standard version with scaled consequences, any desirable additions lying within the specified feasible range(s) of consequences can be evaluated. In fact, one decision maker, while articulating his preferences, suggested some changes, albeit minor, to some options, the value of which could not be determined from the elicited functions.[3]

Second, the possibility of receiving an outcome from the various lotteries that they regard as very bad can make respondents averse to taking any risk at all. This means that at indifference the lottery probabilities are very close to unity for the favourable risky outcome and there is reason to suspect that bias may be present at such extreme probabilities because of perceptual difficulties (Slovic, Fischhoff and Lichtenstein 1976). Moreover, experience during the interviews raised the possibility of breakdown of the independence condition in cases with a strongly disliked option, meaning that respondents may have unduly biased their responses against the lottery with the bad outcome. In eliciting preferences for attributes of specified social objectives in the standard version, the existence of a totally undesirable possible outcome might not be so obvious to the respondent. This seems a distinct disadvantage of the adapted version, at least over the standard version, for policy analyses where the preferences of affected parties are clouded by strong emotions, as in this case study.

Other problems with direct assessment included the infeasibility of consistency checks and the weakness of possible tests of preferential and utility independence, as discussed previously. Moreover, only weak checks of the sensitivity of the rankings of combinations to changes in various elicited values of the elicited functions were possible (Delforce 1982). Such sensitivity analysis is more straightforward using quantitative, continuous attributes. For instance, Keeney and Wood (1977) defined the sensitivity of a set of multiattribute utility theory prescriptions in terms of the changes in measurable attributes needed to make various alternatives equally preferred. Their approach, incidentally, seems to circumvent the problems in policy analysis which arise because of non-absolute cardinal utilities. That is, the extent by which one alternative is better than another for a particular decision maker can be judged by the change that would have to occur in some socially meaningful, measurable attribute of a problem in order for the decision

[3] This might have been largely overcome by undertaking a first run elicitation of the decision makers' functions before the interviews of pastoralists or tourists. The final elicitation might then have been undertaken after the latter interviews. This would have permitted the decision makers to have been informed of the expressed preferences of the user groups prior to their final interviews — the merit of doing this is discussed later.

maker to be indifferent between the two alternatives. The obvious measure to determine, where possible, is the increase in expected cost of the more preferred alternative or the increase in expected benefits of the less preferred one required to achieve indifference. Such sensitivity analysis can identify which alternatives are the 'real contenders' for implementation (Keeney and Wood 1977, p. 711), but unfortunately is infeasible for the case study because of the use of descriptive, discrete options.

There are several disadvantages with the use of the von Neumann–Morgenstern game. A few respondents had difficulty in articulating preferences for changes in the probability of the various lotteries of less than five per cent. Anderson et al. (1977, p. 69) note that some people tend to exhibit preferences for favourite probability numbers and that this distorts the utility assessment. The use of the von Neumann–Morgenstern game also makes the elicitation of scaling constants difficult because of the complexity of the choices faced in, say, lottery L^1. The adapted approach requires difficult choices involving combinations of levels of the five attributes in specifying all five scaling constants of the own preference functions. When quantitative continuous attributes are used an apparently less demanding method for specifying scaling constants can be used requiring respondents to make choices between only pairs of attributes (Keeney and Raiffa 1976, pp. 302–5).

Usefulness for decision makers

From the viewpoint of the usefulness of the case-study results to the decision makers, three possible alternative reactions were envisaged a priori: (a) they would accept the prescription of the multiattribute utility theory analysis in ranking decision options; (b) they would reject the multiattribute utility theory prescribed ranking, viewing the analysis as unhelpful; or (c) they would reject the prescribed ranking (or accept it only if it matched their intuitive ordering), but would nonetheless find the procedure helpful in thinking about the problem.

Both decision makers were quite willing to take part in the research and seemed highly motivated to make carefully considered responses to the hypothetical choices presented to them in interviews. Both, however, expressed doubts about the rankings of alternative combinations derived using multiattribute utility theory and neither was prepared to accept these rankings as clearly superior to his intuitive rankings. Despite this, neither decision maker rejected the method altogether, both apparently finding the analysis helpful in thinking through the problem. After the release of the findings to him, one decision maker expressed the view that the research had made a contribution to the policy choice. Thus, of the a priori possibilities, (c) appears to apply, supporting the proposition in the introduction that decision analysis should be viewed as more than merely a prescriptive device for social decision making.

The decision makers' scepticism about the actual prescriptions may partly reflect the novelty to them of the method of analysis. Indeed, one decision maker stated that, armed with what he had learned about the method, he could articulate his preferences in a repeated analysis in a way that would produce a ranking of combinations more consistent with his intuitive preferences. The adapted version would then apparently, in his view, provide a realistic model of his decision making behaviour and hence an acceptable guide to his choice.

The decision makers' suspicions about the inconsistencies of their multiattribute utility theory prescriptions were undoubtedly compounded by the fact that the research budget permitted one interview only per respondent. This, they felt, forced them to make hasty choices whereas the real decision making process for such important issues is normally spread over a much longer time. Moreover, they felt that such a snap decision making atmosphere was not conducive to a good policy choice. Multiple interviews would have given them a better understanding of the approach by the time of preference articulation and may have permitted a revision of their expressed preferences in the light of experience.

A few of the decision makers' more specific comments on the procedure are of interest. The utility and scaling constant games seemed to them to imply that the decision making process was meant to be a gamble in which the final choice was a random process. They felt this was inappropriate since they were able to influence, if not wholly determine, the choice amongst alternatives. To some extent, of course, these objections reflect the use of decision options rather than their consequences as the attributes of the adapted method. Nevertheless, such utility games in one form or another are the basis of utility assessment and decision analysis. Clearly, decision analysts need to ensure that the games are framed in a way that appears to be as realistic as possible to the decision maker.

Both decision makers said that they found the social welfare functions more difficult to specify than their own preference functions. This was because the idea of explicitly trading utility to pastoralists against utility to tourists was new and rather confusing, and they required more time to think about the choices faced than the interview format permitted. As a consequence, both felt greater confidence that their own preference functions captured their true professional (or official) views than that their social welfare functions captured their altruistic preferences.

The procedure for specifying the social welfare functions is such that the social orderings of combinations appear to come from a 'black box'. Indeed, the procedure involves multiplying together several sets of numbers derived from five separate sets of interpersonal comparisons of utility (at equations (7), (8), (10), (11) and (13)). Given this and given the contentious nature of such comparisons generally, the real contribution toward the policy choice gained from the elicitation of these functions was the new experience for the decision makers of trying to make explicit trade-offs between the utilities of the two user groups. Both decision makers said that they found this experience valuable, even though they doubted the consistency of the results of their first and only attempt at it.

In retrospect, it might have been better to have first disclosed the previously expressed preferences of pastoralists and tourists to the decision makers before eliciting their preference functions. It would normally be expected in the real world that decision makers would utilise the best available information when making a policy choice, and knowledge about the preferences of affected groups is clearly relevant and potentially helpful.

Concluding Comments

The attempt at multiattribute preference elicitation reported in this paper was undertaken with limited time and financial resources. The research therefore does not give a wholly adequate basis for judging whether the method used is capable, under more favourable conditions, of yielding prescriptions acceptable to decision makers. It is clear that, for it to be possible for a fully normative application of the method to succeed, considerable research resources would be required, as well as a reasonably close working relationship between the analyst and the decision makers. The case study has, however, provided some useful pragmatic lessons in terms of the difficulties in preference elicitation. It has also given some indications of the type of assistance that decision analysts might usefully aim to provide to decision makers responsible for decisions of social importance. Moreover, despite its limitations, the research did show that the particular method was useful to the two decision makers in the specific choice they faced.

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