

Valuing Australia's Ecosystem Services Using a Deliberative Multi-criteria Approach

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Abstract

This paper describes one part of a major study being undertaken in Australia at present which involves valuing ecosystem services. The valuation exercise is being based on all the costs and benefits of these services (both monetary and intangible) in a case study region of Australia. Part of this analysis will take a new approach of combining Multi-criteria Decision Analysis with deliberative stakeholder input in the form of a Citizen's Jury. A series of resource use scenarios are to be developed using experts from the case study region. An overall objective of the project and a series of criteria (social, economic and ecological) deemed necessary to meet this objective are to be specified using both expert opinion and stakeholder input. A Citizen's Jury involving stakeholders will be conducted to obtain consensus on a weighting scale for the criteria. 'Expert witnesses' will be called on to provide information where required. Each scenario will be assessed in terms of the identified indicators and criteria weights using a Multi-criteria Analysis. This part of the analysis will provide a framework for the decision problem and identify any trade-offs that may exist between different criteria. Consensus is to be reached, using both the jury approach and the multi-criteria evaluation on a preferred scenario for the region. This approach seeks to combine the advantages of Multi-criteria Analysis in providing structure and integration in complex decision problems with the advantages of deliberation and stakeholder interaction provided by a Citizen's Jury.

1 Introduction

Ecosystem services include the life support activities that ecosystems provide for us, largely in an unrecognised and unpriced way. Examples of these include pollination, nutrient cycling and water regulation. Humans derive benefits from the natural ecosystems in which they live. Often, however, through human intervention, these services from ecosystems fail and costly technological means are sought to make up for this gap. For example, when the important processes of nutrient provision and waste disposal in healthy soils fail, then farmers spend large amounts of money improving soil structure, reducing soil sodicity and applying fertilisers. However, apart from a few isolated examples, we have virtually no appreciation of the nature or the value of the services that ecosystems provide in Australia.

This paper describes an important part of a major study taking place in Australia. The Nature and Value of Ecosystem Services is a project jointly funded by the Myer Foundation (an Australian philanthropic organisation) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). It is a large national project spanning four years of research and differs in both scale and content from most other valuation studies that have been attempted around the world. It brings together scientists, economists, industry, government and communities as collaborators engaged in understanding a system that has social, economic and ecological components [6].

The impetus for the project is based on the innovative and emerging belief that ecosystems can and should be characterised and managed as capital assets (see for example, [10], [7]). This will, in turn, lead to greater investment and collaboration in valuing ecosystems, changes in the policy and practice of land management and to the development of new technologies. These presently unaccounted and unpriced services should be incorporated into the decision-making processes of natural resource management and policy in order to achieve ecologically sustainable development.

A major part of the analysis is the valuation exercise. A valuation of ecosystem services will be carried out based on all the costs and benefits of these services (both monetary and intangible) in a case study region of Australia: The Goulburn-Broken Catchment of Victoria. This analysis will take a new approach of combining Multi-criteria Decision Analysis (otherwise known as Multi-criteria Analysis or MCA) with deliberative stakeholder input in the form of a Citizen's Jury.

The Goulburn-Broken region of Victoria is a large and diverse catchment that incorporates many different agricultural activities including irrigated farming (dairy, horticulture and viticulture) in the lower northern area, to dryland cropping and grazing in the centre and hobby farming and tourism activities in the upper catchment to the south. The catchment is characterised by a myriad of environmental problems including soil salinity, rising water tables and poor water quality. In identifying and valuing the ecosystem services of the catchment, recommendations will be made for overcoming these problems through improved management practices utilising these services.

This paper begins by giving an overview of the theoretical frameworks of both Multi-criteria Analysis and the Citizen's Jury, some problems that may be encountered in undertaking each technique in isolation and the advantages that may result from taking a combined approach. Next, steps in the combined approach will be identified, using issues surrounding the Goulburn-Broken Catchment to exemplify the steps, and finally, some conclusions discussed.

2 Incorporating Participation into Natural Resource Management - The Citizen's Jury

An important aspect of the decision-making stage of resource/environmental policy-making in a democratic society, is the question of 'who decides?' In recent years, increasing attention has been given to incorporating public participation into natural resource policy formulation ([2], [3], [4], [26], [5], [11], [30]). The advantages of allowing public involvement in natural resource decision-making have been well documented and such participation often strives for wider community understanding and therefore sanctioning of the policies concerned [13]. In this way it is hoped that decisions are more likely to command assent and therefore lead to the desired outcomes if they have been formulated with public support. Van den Hove gives justification for participatory approaches to environmental problems based on the characteristics of environmental issues including complexity, uncertainty, large temporal and spatial scales and irreversibility. These physical characteristics can, in turn, have consequences for social characteristics of the environment therefore justifying a participatory approach to decision-making¹ [33, p. 458].

The desire for community involvement in environmental/natural resource policy formulation is also reflected in the growing interest in environmental issues by Australian individuals since the 1970s. Lothian carried out a review of national and state surveys of the attitudes of Australians towards the environment compared to other issues of national significance such as unemployment and inflation. He concluded that over the period 1975 to 1994:

... the environment has remained a significant issue of concern to the community when compared with other issues. This concern is further evidenced by the overwhelming pro-environment choice of Australians when faced with the trade-off between environmental protection and economic development. Pollution and waste are regarded as the dominant environmental concerns, followed by habitat loss, natural resource issues such as land degradation, and finally the global topics of ozone depletion and population growth [18, p. 98].

Bass summarised the benefits of public participation in policy development as:

- more involvement of community and private sector than in government-only processes
- greater public debate and understanding of issues
- increased benefits from more group dynamics
- more relevant local information uncovered
- a broader basis of skills, ideas and inputs result
- a tendency for external inputs to be less dominant
- better consensus on trade-offs provided
- more practical objectives obtained

¹These social characteristics may include 'conflicts of interests between actors', a 'plurality of legitimate standpoints' and 'diffused responsibilities and impacts' [33, p. 461].

- the resulting policy/strategy not surprising stakeholders
- accountability and political credibility aided
- stronger partnerships and commitments to implementation achieved, and
- long run cost-savings from greater resource mobilisation realised [2, p. 22].

Public participation in policy development can take many different forms however, ranging from information exchange between policy makers and the community to active participation in the decision-making process by stakeholders and individuals in the community. Arnstein [1] developed the famous framework of participatory policy-making based on the level of public participation and the techniques used to facilitate this participation. At the highest end of the scale, citizens are given a direct role in decision-making whilst at the lowest end, this role is merely in the form of information exchange between the public and bureaucrats or even just information flowing only from bureaucrats to the public.

One method of incorporating public (in particular, stakeholder) participation into the decision-making process of natural resource management at the higher end of the scale in recent years is the Citizen's Jury. The Citizen's Jury has its origins in Germany in 1969 with Deniel's *plannungzelle* (planning cell) technique. The first Citizen's Jury was conducted in 1971 in the United States by Crosby [14]. Since then, this approach has had widespread use in deciding health issues in Europe [17] and in environmental issues in both Europe [23] and the United States [8]. It has had only limited use in Australia [14].

The Citizen's Jury is based on the model that is used in western-style criminal proceedings. The Citizen's Jury is concerned with a public decision-making process (such as the allocation of health funds or the identification of protected natural resource areas). The typical jury ranges from 10 to around 20 participants. The jury can be selected either randomly or by use of a stratified random sample to make it representative of the population. The jury is usually remunerated for their efforts and is given a specific charge which is well worded, clear and direct. Ideally the process uses a facilitator and the jury is given sufficient time to deliberate, ask questions and call 'witnesses' (or 'experts'). This may take several days. A process involving great complexity and which requires many witnesses may take much longer. Witnesses are chosen on the basis of their expert knowledge and can and should be selected to represent differing viewpoints. The jury should be comfortable that adequate time has been given to all viewpoints. The final outcome is usually a consensus position reached by the jury and usually documented in a report to the relevant agency that has established the jury.

3 Structuring the Decision-making Process - Multi-criteria Analysis

Multi-criteria Analysis (MCA) is a means of simplifying complex decision-making tasks which may involve many stakeholders, a diversity of possible outcomes and many and sometimes intangible criteria by which to assess the outcomes. In many public decision problems, such as those involved with environmental policy, the objectives of the decision may conflict and the criteria used to assess the effectiveness of different policy options may vary widely in importance. MCA is an effective technique in which to identify trade-offs in the decision-making process with the ultimate goal of achieving compromise. It is also an important means by which

structure and transparency can be imposed upon the decision-making process. Its origins lie in the fields of mathematics and operations research and it has had a great deal of practical usage by public planners in such areas as the siting of health facilities, motorways and nuclear reactors [19]. In recent years it has gained popularity as a tool for making decisions involving complex environmental, economic and social issues.

A Multi-criteria Analysis seeks to make explicit the logical thought process that is implicitly carried out by an individual when coming to a decision. In complex decision-making tasks, which sometimes involve many objectives and many decision-makers, this structured process may be lost in the complexity of the issues. In general, a MCA seeks to identify the alternatives or options that are to be investigated in coming to a decision, a set of criteria by which to rank these alternatives and the method by which the alternatives are to be ranked and preferences aggregated. Finally a sensitivity analysis is carried out on the results. The ultimate outcome is a preferred option or set of options that is based upon a rigorous definition of priorities and preferences decided upon by the decision-maker. Several iterations of the above process and interactions between the analyst and decision-maker can aid the decision-making.

Although many specific types of MCA have been formulated, in the context of this research, MCA is primarily regarded as an aid in the process of decision-making and not necessarily as a means of coming to a singular optimal solution. As such, the MCA process is valued for the enlightenment and unravelling of issues that it can provide in the decision-making problem. The process adds to the knowledge of the decision-maker and is greatly aided by including the decision-maker in each step of the analysis. This is one reason why some forms of MCA are regarded as superior to other decision aiding techniques (for example, mathematical programming methods or Cost Benefit Analysis) which more closely resemble a 'black box' approach. Such techniques are designed to provide an 'optimal' result at the end of the analysis, and so they do not necessarily increase the understanding of the important elements of the process, especially to those who are not familiar with such mathematical models. The dangers of optimising techniques resulting in precise numerical results have been criticised for being misleading especially for policy-makers and laypeople who may interpret such precision as being indicative of 'truth':

The use of precise, quantitative data based on monetary valuations (such as market prices) where complexity and uncertainty are pervasive can be misleading. There is a certain degree of comfort associated with precise numbers despite the fact that the unidimensional answer can lack any actual relevance, ie. being precise but wrong [20, p. 8].

MCA, like Cost Benefit Analysis, is a technique that utilises preferences. However, unlike Cost Benefit Analysis, the reasons behind these preferences can be discovered, rather than just the intensity of the preferences.

Such techniques are not designed to unravel the decision-making problem or provide a process that will enlighten the decision-maker and add to the decision-makers knowledge of the problem. The non-transparency and singular solution nature of such techniques may only result in increased mistrust in the process by those who are not familiar with how a decision was finally derived [24]. The approach followed in this current research is therefore similar to the 'heuristic' approach emphasised by Stirling and Mayer [31] in their 'Multi-criteria Mapping' technique.

In Australia, the use of MCA has been minimal and even less so in the area of environmental policy except for its trial application to forest policy by the Resource

Assessment Commission [27] and some applications to transportation problems and natural resource planning ([25], [12], [28]).

4 Advantages and Disadvantages of Both Approaches in Isolation

Multi-criteria Analysis has the advantage of being able to provide a framework to complex decision-making problems that allows the problem to be broken down into workable units and to be structured in such a way that enables the complexities of the problem to be unravelled. This is done essentially through the process of identifying objectives, criteria and indicators. Applying MCA in a heuristic way enables the MCA to aid in the learning process of complex issues. In theory and in practice however, MCA does not adequately address the facilitation issue of interaction between analyst and decision-makers to elicit preferences and to revise preferences as part of the iterative process particularly with multiple decision-makers. With multiple decision-makers, MCA does not provide clear guidelines on how to analyse or aggregate multiple weights.

Citizen's Juries, on the other hand, do allow for an effective approach of interaction between multiple decision-makers and for conducting an iterative process chiefly through the deliberative aspects of the jury approach. In effect, the Citizen's Jury approach aggregates multiple preference weights through deliberation to achieve consensus. In general however, Citizen's Juries have not addressed the problem of structuring the decision-making task. Lenaghan found that juries that had a structured and well focused agenda performed and were able to engage much better than those that had to deal with large-scale unfocused problems [17, p. 53].

A logical progression to overcome the problems and to enhance the advantages of both methods is to combine the two approaches. A new form of decision-making aid which will combine the facilitation and deliberation qualities of the Citizens Jury process with the analytical and integrating qualities of the Multi-criteria Analysis technique will now be described.

5 A Combined Approach - Steps in the Analysis

5.1 Choosing the jury

Jurors can be selected based on a demographic overview of the population that will be affected by the decision. The choice of jurors can be made using a random sample or a stratified random sample of this relevant population. A recently conducted Citizen's Jury in New South Wales used a selection process based on a telephone survey in which both demographic and attitudinal data was collected. These data included gender, age, place of residence, ranking of the environment in relation to other social issues, occupation, income, income source and level of education [15].

5.2 Choosing the options and the objectives

The choice of options and of the overall objective or objectives are important and closely related steps in any decision-making process. Although the objectives and options should be chosen by the jury, input from other sources, such as expert

Table 1: Key Issues in the Goulburn-Broken Catchment

Management Issues	
1	Integrating management across ecosystems by: - re-establishing flood plain - alternative re-vegetation strategies - nutrient management
2	Managing land-use intensification
3	Managing transitions in land-use
4	Managing vegetation for the full suite of ecosystem services
5	Managing cultural, heritage and option values
6	Maintaining soil health
7	Accounting for the value of non-agricultural land and water uses
8	Water and salinity management
9	Anticipating and adaptively managing emerging issues
Source: [9]	

advice, can occur. The options may even be based on output from computer simulation models. Often, the options and objectives that are to be decided upon are already given, for example, by the political process. The objective can be as broad as necessary, but in the case of multiple decision-makers, overall agreement should be reached. The options could reflect each of the preferred scenarios of the decision-makers or could be based on an amalgamation of plans of the decision-makers. Massam [19, p. 36] suggests a benchmarking approach as a framework for the options which should include:

- the status quo,
- an ideal best plan,
- an hypothetical worst plan, and
- a plan of minimum satisfaction.

The options should be sufficient in number, however, to represent a realistic selection for the decision-maker but should not be too numerous to make the analysis unwieldy or unnecessarily complex. Often, options can be rejected on the basis of budgetary or other constraints.

For the Goulburn-Broken Catchment study, a preliminary set of options have been chosen from a previous analysis which identified key natural resource management issues of concern in the Catchment (Table 1). The options will be ratified or, if necessary, altered by the jury.

A preliminary objective and a number of sub-objectives have also been identified for the catchment. The approach will be to evaluate a number of specific sub-options such as floodplains, re-vegetation, culture and tourism issues in order to build up an overall set of land-use change options for the catchment. Again, the objectives and sub-objectives will need to be ratified by the jury. The charge for the jury will be to decide upon a particular option that best meets the overall objective. Figure 1 shows an example of an objective and some sub-objectives for the Catchment.

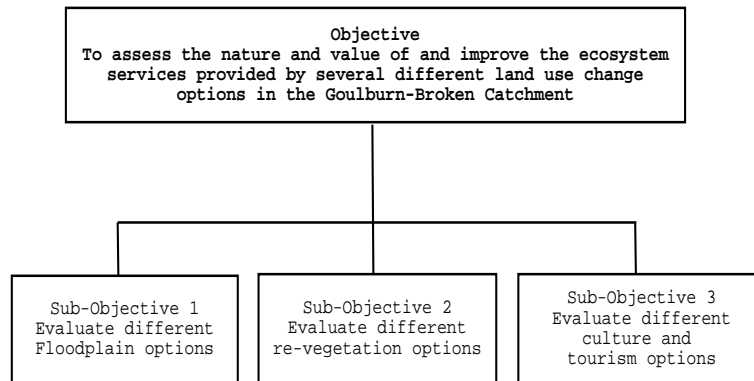


Figure 1: An Example of Objectives and Sub-objectives

5.3 Selecting the criteria

The jury will be given the task of selecting the criteria. The criteria are designed to compare and assess each of the options and therefore must relate to the overall objective of the decision-making task. Initially, criteria can be very broad and then broken down into components or sub-criteria and even lower level sub-criteria. Ideally, the lowest level of the criteria structure are those which are measurable (quantitatively or qualitatively) and are known as indicators.

In general, the criteria should be complete and exhaustive in that they cover all possible aspects of the decision-making problem and make the analysis complete. The criteria should also contain mutually exclusive (non-redundant) items so as to prevent 'double counting' of aspects of the decision-making problem and to better allow 'trade-offs' to take place. The criteria should be clearly defined and directly relevant to the defined problem. Because it is often necessary to break criteria down into sub-criteria in order to make meaningful measurements, they should be decomposable into smaller measurable units. For example, a criterion such as 'quality of life' may be measured as an index based on the sub-criteria of level of income, access to health care and level of education. This relates to the next attribute, which is that the criteria should be minimal so that no other smaller set of criteria can be measured. Finally, the number of criteria should ideally be restricted so that weighting the criteria does not become unmanageable or difficult.

Advice on the number of criteria or sub-criteria in any group varies but most practitioners regard 7 to 12 criteria as the maximum ([34, p. 8], [27, p. 17]). However, one type of MCA, the Analytic Hierarchy Process or AHP [29] manages large numbers of criteria by utilising an hierarchical framework. Under this technique, when the number of objectives or criteria become large, then a hierarchical structure of objectives or criteria is imposed. Nijkamp et al. [22] regard one important advantage of this approach to be that a subconscious bias towards data rich criteria and indicators is avoided.

The AHP method recommends an interactive process in which a decision-maker or group of decision-makers relay their preferences to an analyst and can debate or discuss opinions and outcomes. It largely stems from the theories of human behaviour including thought process, logic, intuition, experience and learning theories [29].

The hierarchies are made up of:

- Top level - comprises the overall objective of the decision process

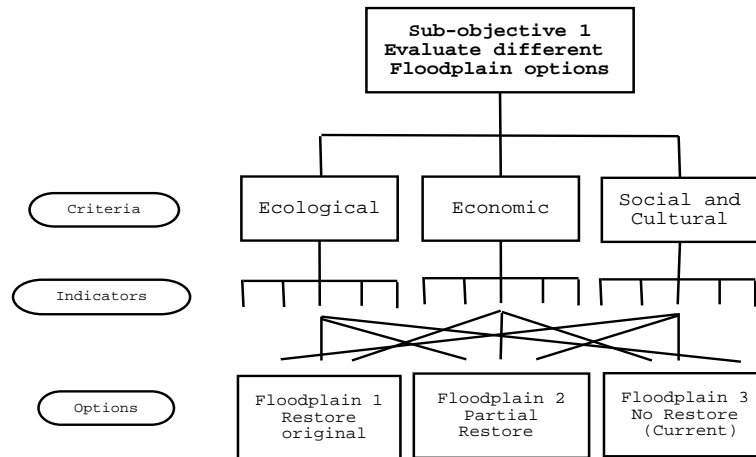


Figure 2: A Decision Hierarchy

- Intermediate levels - comprise the criteria and sub-criteria to analyse the decision
- Lowest level - lists the alternative options that are to be analysed and decided between.

Figure 2 provides an example of a decision hierarchy for one of the sub-objectives of the Goulburn-Broken case study. The sub-objective is evaluated by a set of three broad criteria groupings under the headings of Ecological, Economic and Social and Cultural criteria. Under each of these criteria are the indicators. Each indicator will have a specific value under each of the different options. These sets of values can then be used to assess how well each option meets the sub-objective.

5.4 Weighting the criteria

In Multi-criteria Analyses, the preferences of the decision-maker are accounted for by the weighting or scoring placed on each of the criteria and sub-criteria. These weightings may range from equal importance of all criteria, to a ranking of most to least important or to a relative weighting of all criteria. The weights may be qualitatively expressed, quantitatively expressed or a mixture of both. In analyses which involve many different decision-makers, this can be the most important and informative part of conducting the whole process. It allows stakeholders to express differing views explicitly and it helps identify those areas which are of most importance to them and which warrant careful investigation. The weightings make explicit those areas which may ultimately require possible trade-off solutions and thus they provide a greater focus for a complex decision problem.

When the analysis concerns only one decision-maker, the mathematical incorporation of the preference weights into the decision-making problem is relatively straightforward. When it concerns more than one decision-maker, the process becomes more complex and controversial. Under some techniques, a matrix of different preference weights for different decision-makers is reduced to a single vector in order for a single optimal solution to be found. Such a reduction may be performed by taking a simple average, a modal or even a median figure over the range of the weights, but such reductions may lose important trade-off information related to the outcomes of

the analysis under extreme weightings. There is no clear consensus in the literature on how to reduce many different preference weightings for the criteria.

The Citizen's Jury process could be used to great advantage in determining the weights of the criteria. The jurors could discuss the relative merits of each of the criteria and even call expert witnesses if necessary to help them reach a consensus on the weights. If consensus is not reached initially, then those criteria of greatest contention in priorities would be the subject of greater scrutiny in the process.

The weighting process of the AHP is based upon the construction of a series of 'pair-wise comparison' matrices which compare criteria to one another. This is done to estimate a ranking or weighting of each of the criteria in their contribution to the overall objective. The ultimate aim will be to determine, for each decision-maker, a weight vector w .

5.5 Assessing the options

The options are assessed in two stages: first, by how important each of the criteria and sub-criteria are to the decision-maker (the weight vector w) and second, by how well each option rates in terms of each of the criteria and sub-criteria of assessment.

The second stage is displayed by means of an Impact Matrix M , where each of the components, the m_{ij} , represent the evaluation or impact of the j th option according to the i th criterion. In other words, the Impact Matrix shows the performance of each option according to the individual criteria.

Solving the typical discrete multi-criteria decision problem involves:

A : a finite set of $i = 1...I$ feasible options;

G_j : the evaluation criteria used to assess the options, where G_j maps the set of options onto the real number line i.e. $G_j : A \rightarrow R$ for all $i = 1...I$;

If A has two elements, a and b and a is regarded as being a better solution than b according to the j th criterion, then $G_j(a) > G_j(b)$ [21].

The final ranking of each of the options is then calculated by a mathematical operation using the Impact Matrix and the criteria/sub-criteria weights. The form of this mathematical operation (often referred to as the 'aggregation procedure', [21]) often describes the particular type of Multi-criteria Analysis employed, such as the Analytic Hierarchy Process.

The jury would be asked to fill in the values of the Impact Matrix (i.e. the 'impacts'). They could do this by calling on expert witnesses (who could in turn be analysts that have quantitative models to aid them). Values could be either quantitative or qualitative. An example of an Impact Matrix, listing some possible environmental (assumed here to be all ecosystem services), economic and social and cultural criteria, is provided in Table 2. Possible indicators to measure these criteria are also listed.

5.6 Sensitivity analysis

There are several reasons why a sensitivity analysis should be undertaken. The first is to take into account the uncertainty in estimating some of the figures involved in the Impact Matrix. The impacts of the various options under different criteria may fall within a statistically estimated range that can be incorporated into the analysis.

Table 2: Example of an Impact Matrix for a Land Use Decision Problem in the Goulburn-Broken Catchment

		Impacts*		
Ecosystem Service Criteria	Possible Indicators	Option 1	Option 2	Option 3
Pollination	Pollination sensitivity to landuse			
Life Fulfilment	Impact of landscape change on landuse			
Climate Regulation	Capacity to adapt Carbon sequestration			
Pest Control	Costs of control Costs of alternatives			
Genetic resources	Biodiversity index			
Habitat	Area of vegetation No. of species			
Shade and Shelter	Area of shade species			
Water Health	Salt concentration			
Economic Criteria				
Economic benefits	Land price rises Income form timber			
Economic costs	Costs of site mangt. Costs of revegetation			
Social and Cultural Criteria				
Aesthetic, cultural and spiritual values	Qualitative indicators			
*Values to be assessed				

Sensitivity analysis can also consider the effects of different techniques used in the weighting procedure, for example.

It is important that the sensitivity of outcomes are tested for different values of the most crucial and contentious criteria and impacts. For example, if the jury found that there was a great disparity in preferences for a certain criterion then it may be enlightening to find out how the overall results change with the changes in preference levels for this criterion. If the results are not greatly affected, then the criterion can take less importance in the overall process and the jury can concentrate on other criteria and trade-offs. If the results are extremely sensitive to this criterion, then closer scrutiny should be given to it by confirming values and measurements.

The sensitivity analysis is given a dominant role in a technique incorporating multiple decision-makers and risk analysis called Multi-criteria Mapping [31]. 'Mapping' refers to that part of the analysis where the results are expressed in terms of various, systematically applied, sensitivities with '... prescriptive conclusions being drawn only conditionally, by reference to the clearly-defined perspectives taken by different participants' [31, p. 69]. Another example of sensitivity analyses accounting for risk and uncertainty involved with the data uses Monte Carlo simulation to estimate probability distributions for the underlying data sets so that the estimated means and variances of the data can be incorporated to assess outcomes [32].

5.7 Interacting and iterating

The analyst can achieve greater understanding of the decision-making problem by interacting with the jury to allow further iterations in the analysis if necessary and also to identify where trade-offs can be made. Often, interaction and further iterations can be facilitated by the use of computer software models that allow for faster manipulation of the data. Also the use of graphical interfaces can be linked to various parameters of the MCA to aid in the decision-making. For spatial data, one promising but little used technique for interacting with the decision-maker is the incorporation of geographical information systems into the Multi-criteria Analysis [16]. For example, for a decision concerning different areas of land being put to different purposes, it could be possible to link the outcomes of a Multi-criteria Analysis to a graphical interface depicting these different land-use options. In the Citizen's Jury, the process of interaction between the analyst, jurors and witnesses as well as allowing for several iterations of particular aspects of the analysis will be crucial for ultimate compromise on the outcome to be reached.

6 Summary and Conclusion

This paper has introduced some advantages and disadvantages of two decision-aiding techniques and has argued that advantages may be enhanced and disadvantages overcome by combining the two approaches. Some practical steps on how this might be achieved have been presented here and these steps will be applied to a case study identifying and valuing ecosystem services in the Goulburn-Broken Catchment of Victoria, Australia. In this application it will be shown how the advantages of Multi-criteria Analysis, in providing structure and integration in complex decision problems, can be combined with the advantages of deliberation and stakeholder interaction provided by a Citizen's Jury.

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