Environment and Planning C: Government and Policy 2006, volume 24, pages 169 – 190

DOI:10.1068/c22s

Deliberative multicriteria evaluation

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Received 14 April 2003; in revised form 14 January 2004

Abstract. Multicriteria evaluation (MCE) is a well-tried and effective procedure for structuring and aiding complex decisionmaking processes, especially those involving environmental considerations. Formal deliberative processes have also been successful in aiding understanding and meeting consensus in complex and difficult decision problems which involve more than one decisionmaker. Here, both approaches are combined in a new technique called 'deliberative multicriteria evaluation' to assist a group of natural resource managers to decide on a suitable option for recreation and tourism activities in the upper Goulburn – Broken Catchment of Victoria, Australia. This approach is an attempt to combine the advantages of MCE, providing structure and integration in complex decision problems, with the advantages of deliberation and stakeholder interaction provided by a 'citizens' jury'. An important outcome of the process was the discovery of some crucial aspects of the decision problem that required deeper understanding and assessment if that preferred strategy were to have the desired results. Some suggestions for improving the process are provided but, in general, the stakeholder jury was regarded as a helpful and useful procedure by the decisionmakers and one which aided them in their understanding of the issues of a complex decisionmaking problem.

1 Introduction

The Goulburn – Broken Catchment of Victoria, Australia, covers an area of 2.4 million ha that stretches from just north of Melbourne in the south to the Murray River in the north (figure 1, over). The catchment is characterised by substantial environmental problems including soil salinity, rising water tables, and poor water quality. About 200 000 people live in the catchment and land uses include irrigated dairying and horticulture in the lowland parts; dryland grazing and cropping in the middle regions; and hobby farming, tourism, and recreational uses in the southern highland areas. The case study reported in this paper refers to this last part of the catchment (known as the 'upper catchment').

The upper catchment is renowned for providing the opportunity to the population of nearby Melbourne (3.4 million people) to enjoy the magnificent scenery and tourism activities that are offered there, including skiing, four-wheel driving, bushwalking, camping, horseriding, and sightseeing. The influx of tourists (around 2 million) each year has, however, caused serious environmental problems for the area which need to be addressed quickly. Many of these problems are related to water issues in the catchment, which have flow-on effects for users further downstream. Both the Goulburn and Broken Rivers flow into the Murray River, which has its mouth near the city of Adelaide in South Australia. Issues which affect water in the upper catchment therefore may also affect water as far away as Adelaide.

In this study, the complex issues of tourism management are addressed by using a deliberative process aided by multicriteria evaluation. This work is part of a larger

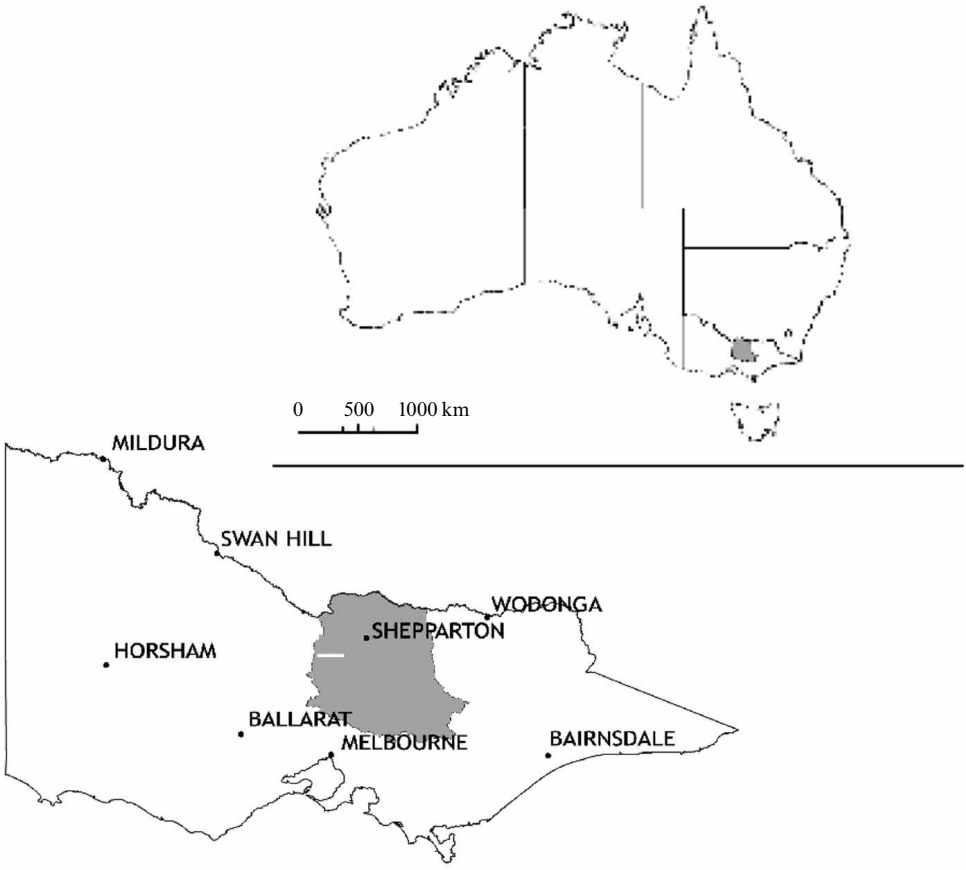

Figure 1. The Goulburn – Broken Catchment of Victoria, Australia.

study that seeks to find out more about the nature and value of ecosystem services in Australia (The Ecosystem Services Project, http://www.ecosystemservicesproject.org/).[(1)] In identifying and prioritising the ecosystem services and other decision criteria, recommendations for improved management of recreation and tourism in the upper catchment are made.

Ecosystem services are the life-support activities that ecosystems provide for us, in a largely 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

[(1)] The Ecosystem Services Project studied the services people obtain from their environments, the economic and social values inherent in these services, and the opportunities that can arise from considering these services more fully in land-management policies and decisions. The project gave scientists and communities the capacity to deliver the right information to policymakers to enable them to move towards more sustainable land-management practices. The Ecosystem Services Project was initiated by The Myer Foundation—a philanthropic organisation—and CSIRO Sustainable Ecosystems.

isolated examples, we have virtually no appreciation of the nature or the value of the services that ecosystems provide in Australia (Cork and Shelton, 2000; CSIRO, 2001).

We begin by giving an overview of the theoretical frameworks of multicriteria evaluation (MCE) and the deliberative process, the citizens' jury, upon which this work is based. Some problems that may be encountered in undertaking each technique in isolation, and the advantages that may result from a combined approach, are then reported. Next steps in the combined approach are identified, and then a case study of the deliberative multicriteria evaluation is detailed. Here, a group of six natural resource managers involved in recreation and tourism management in the catchment were chosen as jurors. One of the options that they were considering as part of the decisionmaking process was the recreation and tourism strategy that they had already developed for the region but which was yet to be implemented. The inclusion of this strategy was to test whether it met their expectations and priorities that were to be made explicit in the process, and whether it could be improved as a result of the deliberative process. Finally, some conclusions are discussed.

2 Incorporating deliberation and participation into natural resource management—the citizens' jury

An important aspect of the decisionmaking 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 the incorporation of public participation in natural resource policy formulation (Cassells and Valentine, 1988; Fagence, 1977; Ross et al, 2002; Spash, 2001). The advantages of allowing public involvement in natural resource decisionmaking have been well documented, and such participation often strives for wider community understanding and, therefore, sanctioning of the policies concerned. In this way it is hoped that decisions are more likely to command assent and therefore lead to the desired outcomes as they have been formulated with public support. Van den Hove (2000) 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 decisionmaking.[(2)]

Out of this desire for community involvement in decisionmaking processes for environmental policy formulation came the growing interest in Australia in recent years in a process which combines public participation with deliberation—the 'citizens' jury'. The citizens' jury has its origins in Germany in 1969, with Dienel's *Planungszelle* (planning cell) technique (Dienel and Renn, 1995). The first citizens' jury was conducted in 1971, in the United States, by Crosby (1999). Since then, this approach has had widespread use in deciding health issues in Europe and in environmental issues both in Europe and in the United States (see, for example, Kenyon et al, 2001). It has had limited, but growing, use in Australia (see, for example, James and Blamey, 2000; Robinson et al, 2002).

The citizens' jury is based on the model that is used in Western-style criminal proceedings, and often involves a public decisionmaking process (such as the allocation of health funds or the identification of protected natural resource areas). The typical jury ranges from around ten to twenty participants. The jury can be selected either randomly or by the use of a stratified random sample to make it representative of the population. The jury is usually renumerated for its efforts and given a specific charge

[(2)] These social characteristics may include conflicts of interests between actors; a plurality of legitimate standpoints; and diffused responsibilities and impacts.

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 is usually documented in a report to the agency that established the jury.

3 Structuring the decisionmaking process—multicriteria evaluation

Multicriteria evaluation (MCE), also known as multicriteria decision analysis (see, for example, Bana e Costa, 1990; Gal et al, 1999; Munda, 1995), is a means of simplifying complex decisionmaking 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 objective of the decision may be in conflict and the criteria used to assess the effectiveness of different policy options may vary widely in importance. MCE is an effective technique with which to identify trade-offs in the decisionmaking process, with the ultimate goal of achieving compromise. It is also an important means by which structure and transparency can be imposed upon the decisionmaking 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 (for example, Bana e Costa, 1990). In recent years it has gained popularity as a tool for making decisions involving complex environmental, economic, and social issues (for example, Beinat and Nijkamp, 1998; Proctor, 2001).

An MCE seeks to make explicit the logical thought process that is implicitly carried out by an individual when coming to a decision. In complex decisionmaking tasks, which sometimes involve many objectives and many decisionmakers, this structured process may be lost in the complexity of the issues. In general, an MCE 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, the preferences or weights the stakeholders assign to the various criteria, and an aggregation procedure by which the criteria-specific rank orders are aggregated into a single 'compromise' rank order. This last step should involve an extensive sensitivity and robustness analysis (Roy, 1998) to explore how different preferences affect the outcome of the aggregation and how robust the compromise rank order is with respect to deviations in the preferences. 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 decisionmaker. Several iterations of the process and interactions between the analyst and decisionmaker can aid the decisionmaking. Although many specific types of MCE have been formulated, in the context of this research MCE is primarily regarded as an aid in the process of decisionmaking and not necessarily as a means of coming to a singular optimal solution. As such, the MCE process is valued for the enlightenment and unravelling of issues that it can provide in the decisionmaking process. The MCE process adds to the knowledge of the decisionmaker and is greatly aided by the inclusion of the decisionmaker in each step of the analysis. The approach followed in this current research is therefore very much within a heuristic framework.

4 Advantages and disadvantages of both approaches when used in isolation

MCE has the advantage of being able to provide a framework for complex decisionmaking problems that allows the problem to be broken down into workable units and to be

structured in such a way that the complexities of the problem can be unravelled. This is done essentially through the process of identifying options, criteria, and preferences. Applying an MCE in a heuristic way enables the MCE to aid in the learning process concerning complex issues. In theory and in practice, however, MCE does not adequately address the facilitation issue of interaction between analyst and decisionmakers to elicit and revise preferences (see, for example, Klauer et al, 2006). With multiple decisionmakers, MCE does not provide clear guidelines on how to analyse or aggregate multiple weights. Most MCEs provide some sort of average over the various weights provided, and therefore important information concerning the extent of different priorities is lost in the process. Citizens' juries, on the other hand, do allow for an effective approach of interaction between multiple decisionmakers with dispersed priorities, and for conducting an iterative process—chiefly through the deliberative aspects of the jury approach. In effect, the citizens' jury approach aggregates multiple preference weights through deliberation to achieve consensus. In general, however, citizens' juries have not addressed the problem of structuring the decisionmaking task. Lenaghan (1999, page 53) 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.

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 decisionmaking aid which will combine the facilitation and deliberation qualities of the citizens' jury process with the analytical and integrating qualities of the MCE technique is now described. To our knowledge, this combination of the two techniques has not been attempted before.

5 A combined approach—steps in a deliberative multicriteria evaluation

Here, we describe the decision process in a general manner. An overview is given in figure 2.

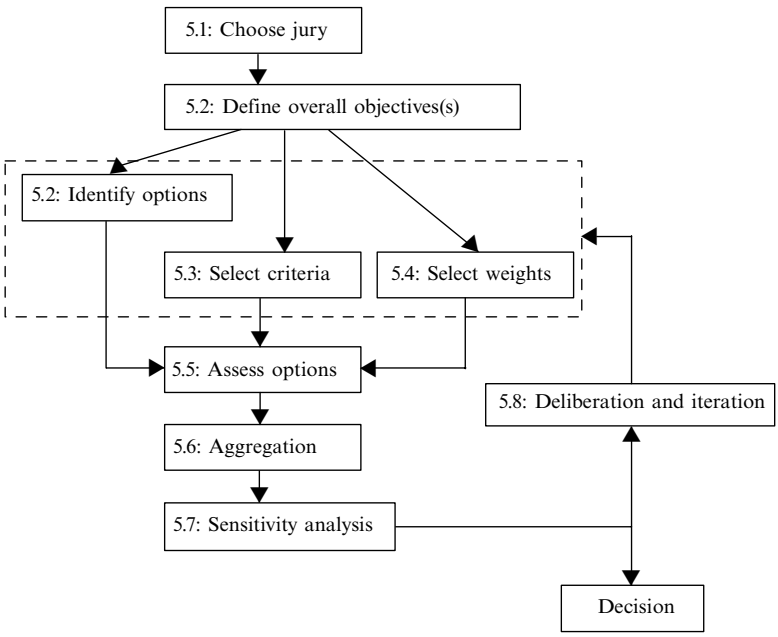

Figure 2. Flowchart of the deliberative multicriteria decision process.

5.1 Choosing the jury

For a citizens' jury, the 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 from a random sample or from a stratified random sample of this relevant population. The selection of members of citizens' juries may be by a process based on a telephone survey, in which both demographic and attitudinal data are collected. Such data include gender, age, place of residence, ranking of the environment in relation to other social issues, occupation, income, income source, and level of education. In this present study, the jurors were natural resource managers—the decisionmakers in charge of strategies for recreation and tourism in the region.

5.2 Choosing the options and the overall objectives

The choice of options and of the overall objective or objectives of the decision (that is, those that are to be met ultimately by the chosen option) are important and closely related steps in any decisionmaking process. Although the jury should choose the objectives and options, input from other sources, such as expert 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 decisionmakers, overall agreement should be reached. The options could reflect each of the preferred scenarios of the decisionmakers, or could be based on an amalgamation of plans of the decisionmakers. Massam (1988, page 36) suggests a benchmarking approach as a framework for the options which should include:

(a) the status quo,
(b) an ideal best plan,
(c) a hypothetical worst plan, and
(d) a plan of minimum satisfaction.

The options should be sufficient in number, however, to represent a realistic selection for the decisionmaker but should not be so numerous as to make the analysis unwieldy or unnecessarily complex. Often, some options can be rejected on the basis of budgetary or other constraints. The chosen objective(s) should reflect the desired outcome for the decisionmaking process to give clear and unambiguous purpose to the chosen option. In this case study, the jurors were responsible for choosing the options.

5.3 Selecting the criteria

The jury should be given the task of selecting the criteria which are designed to be used to compare and assess each of the options, and must therefore relate to the overall objective of the decisionmaking task. Criteria can initially be very broad and then broken down into components or subcriteria, and even lower level subcriteria. Ideally, the lowest level of the criteria structure is those criteria 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 decisionmaking problem and make the analysis complete; at the same time, the criteria should be mutually exclusive (nonredundant) so as to prevent 'double counting' of aspects of the decisionmaking problem and to allow the main trade-offs to be clearly identified (see, for example, Bouyssou, 1990). The criteria should be clearly defined and directly relevant to the problem under consideration. Because it is often necessary to break criteria down into subcriteria 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 subcriteria 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 subcriteria in any group varies, but most practitioners regard seven to twelve criteria as the maximum (Yoon and Hwang, 1995, page 8).

Decisions concerning the environment and natural resource management can often be broken down into the broad criteria groupings of 'ecological', 'economic', and 'social and cultural'. In this case study, the jurors carried out the selection of criteria.

5.4 Weighting the criteria

In MCE, the preferences of the decisionmaker are accounted for by the weighting placed on each of the criteria and subcriteria. 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 (such as 'criterion *x* is twice as important as criterion *y*') (see, for example, Bana e Costa, 1990). The weights may be qualitatively expressed, quantitatively expressed, or a mixture of both. In analyses which involve many different decisionmakers, this can be the most important and informative part of the whole process: it allows stakeholders to express differing views explicitly and it helps identify those areas which are of most importance 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 decisionmaker, the mathematical incorporation of the preference weights into the decisionmaking problem is relatively straightforward because here the preferences are unique (coming only from one person) and the only task is to elicit these preferences. There exists a wide range of methods for the elicitation of an individual's preferences (see, for example, Beroggi, 2000; Maystre and Bollinger, 1999). When more than one decisionmaker is involved (a so-called 'group decision'), the process becomes more complex and controversial as now the preferences or weights are not unique but vary among the participants in the decisionmaking process. Assuming that the preferences of each decisionmaker can be expressed by a vector of quantitative weights (one weight for each criterion), the result is a *set* of weight vectors. This variability and the set of weight vectors may be reduced to a single weight vector by taking a simple average, a modal, or even a median figure over the range of the weights. However, such reductions may lose important trade-off information related to the outcomes of the analysis under extreme weightings. Moreover, decisionmakers whose weights are very different from the calculated averages are most likely to disagree to such a technocratic enforcement of a 'consensus' and may not wish to participate in the process any further. There is no clear consensus in the literature on how to reduce such weight variability among decisionmakers.

The jury process can be used to great advantage in determining the weights of the criteria. The jurors discuss the relative merits of each of the criteria, and call expert witnesses if necessary to help them reach a consensus on the weights. If consensus is not reached initially, then those criteria for which there is greatest disagreement with respect to priorities would be the subject of greater scrutiny in the process (see below).

5.5 Assessing the options

In addition to the weightings of the criteria, the second component required in an MCE is the assessment of the options with respect to each individual criterion or subcriterion. The result of this multicriteria assessment is an 'impact matrix', of which each element represents the evaluation or impact of an option according to a particular criterion. Each criterion identifies a rank order of options determined by the degree to which each option performs in the particular criterion. Considering all of the criteria, the decisionmakers (even if there is only one) are faced with a set of rank orders of

options that are most likely to differ from each other, because any individual option may naturally perform well in one criterion and poorly in another. In order to obtain a single 'compromise' rank order, these rank orders have to be aggregated in some way.

5.6 Aggregating the criteria

There exists a wide range of aggregation algorithms (see, for example, Bana e Costa, 1990; Gal et al, 1999; Refsgaard, 2006). The aggregation procedure used in the present study is based on the PROMETHEE (preference ranking organisation method for enrichment evaluations) multicriteria decision aid in which an outranking procedure is used as the basis of evaluation (Brans and Mareschal, 1990). This procedure is utilised through the software program ProDecX, which calculates a 'net flux' to determine the ranking of the option (the higher the net flux, the higher the rank) and is also able to account explicitly for uncertainty when assessing various options (for more details, see Klauer et al, 2006).[3]

In ProDecX, for each criterion, the weights are sampled from the weights given by the decisionmakers in a fair way, that is, the weighting of each decisionmaker contributes equally to the final results. Given the various weights from the different decisionmakers, the software determines, for each option, the mean and standard deviation of the net flux. The standard deviation of the net flux is a very important indicator of whether there is consensus on the rank order of options or not: the smaller the standard deviation compared with the differences between the average net fluxes of two options, the more conclusive the ranking, that is, the higher the consensus.

5.7 Sensitivity analysis and deliberation

Sensitivity analysis is a well-known and widely used tool for the investigation of the impact of uncertainty and variability on the outcome of a particular analysis (see, for example, Saltelli et al, 2000). For instance, one might explore how sensitively the rank of an option depends on its performance in a particular criterion. An entirely new application appears in the present study, where MCE is combined with a citizens' jury given the task of finding consensus. From the point of view of decisionmaking, the problem here lies in the fact that different sets of weights are likely to lead to different rank orders of options. The role of sensitivity analysis, then, is to explore how sensitively the variability in the rank order of options depends on the variability of each and/or the whole of the criteria weights. Knowledge of these sensitivities allows us to assess:

(a) how critical a consensus on the criteria weights is;

(b) for which criteria is a dissent on the weights most responsible for the variability in the rank order—which points to those criteria where deliberation and the effort of finding consensus should be targeted; and

(c) at which point in the decision process sufficient consensus on the criteria has been reached in order to come to a fairly unique rank order of options.

5.8 Interacting and iterating

The use of sensitivity analysis in the way described above considerably differs from conventional sensitivity analysis in that the analyst is not performing the calculations alone in his or her laboratory, but in a situation where close and real-time interaction with the decisionmakers is crucial. This includes the continuous update of the decisive parameters (for example, new criteria or options may be included or dropped, and/or

[3] Uncertainty in the performance of the options is explicitly considered and lowers the pairwise preferences: the less sure one is that an option *a* performs better than another option *b*, the less strong the preference for *a* over *b* is. ProDecX contains a probabilistic model to measure this effect. Further details concerning ProDecX may be obtained from M Drechsler (martind@oesa.ufz.de).

some criteria may be dropped or simplified, and/or the weights of criteria may be modified) and iterated analyses as the deliberation goes on. Often, interaction and further iterations can be facilitated by the use of computer software models that allow for faster processing of the data. Also, the use of graphical interfaces can be linked to various parameters of the MCE to aid in the decisionmaking. In the citizens' jury, the process of interaction between the analyst, jurors, and witnesses, as well as allowing for several iterations of particular aspects of the analysis, is crucial for ultimate compromise on the outcome to be reached.

6 The case study

6.1 Preparing the stakeholder jury

As mentioned previously, the jury chosen in this study (see section 5.1) comprised six natural resource managers (stakeholders), rather than randomly chosen members of the public (citizens), and has therefore been termed a 'stakeholder jury' to distinguish it from a 'citizens' jury' (the same procedures for the jury are applicable, however).[(4)] This choice was made because of the history of the larger Ecosystem Services Project to which this case study belongs. The stakeholders (hereafter referred to as the 'jurors') had already been chosen to review issues involving recreation and tourism in the area, and were therefore well placed to take part in this initial experiment on the deliberative MCE. Some of the jurors had also been involved in the development of a strategy for recreation and tourism management (later referred to as the 'mix' option) which, at the time of conducting the jury, was about to be implemented in the region.

As part of the preparation for the day of the jury, a special meeting was held some months before 'jury day' to devise a series of management options (section 5.2), a set of objectives for the chosen options (section 5.2), and a set of decision criteria (section 5.3) by which these options could be assessed (see below). This process involved discussions about key issues involved with recreation and tourism in the catchment and, from these discussions, some options for the future direction of recreation and tourism in the catchment, as well as the objectives of these options and some criteria by which to judge the performance of these options, were developed. After this issues workshop, the outcomes were summarised in a small report which was mailed out to the jurors for further consideration and comment as well as for their agreement on the exact wording and details of the options, objectives, and criteria. The agreed objectives of the exercise were to:

(a) protect and enhance the environment and natural attributes of the catchment that attract recreational users; and

(b) balance recreational development and use of the catchment (particularly in riparian zones) with the social, environmental, and economic values of the community.

Also at this time, a questionnaire was distributed to identify preliminary rankings on the decision criteria (section 5.4). Each juror was asked to indicate from 1 (high) to 13 (low), his or her ranking or priority with regard to each criterion; the possibility for criteria to be ranked equally was allowed.

6.2 Options (section 5.2)

6.2.1 *List of options*

The preparatory process described above defined the following options. The options were developed to cover as exhaustive a range of future outcomes as possible.

[(4)] The process follows the structure described in section 5. Here and below, the numbers in parentheses refer to the corresponding subsection as well as to the corresponding box in figure 2.

Business as usual (current) This option represents the current scenario for the recreation and tourism industry in the region. Carrying on with the current practice raises a number of concerns. These concerns include the effects of growing numbers of tourists which will result from population increases; improved vehicles and better roads making access easier; and increased international demand for recreation in the area.

Maximise ecosystem services outcomes (max ES) This option essentially means a policy of no access to any of the recreation and tourism sites that are under threat from environmental damage (including national parks and state forests in the region). The benefits to ecosystem services would be immense, but these would come at enormous cost to the local community from the lack of domestic tourists, and also costs to the state from a lack of international tourists. There would also be costs to all individuals in terms of the loss of aesthetic experience.

Maximise social outcomes (max S). This option emphasises employment for local people and therefore targets issues such as job creation and job training in the recreation and tourism industries. This includes jobs and training in such activities as ecotourism, four-wheel drive tours, camping excursions, environment education tours, and expansion of the local hospitality and accommodation markets. There is little concern for the impact on ecosystem services which are not noticeable to tourists (for example, water quality), but the impacts of activities on visible ecosystem services (such as the aesthetic appeal of a site) would have to be taken into account as without these visible services there would be no tourism industry.

Maximise economic outcomes (max Ec) This option represents the policy of access to all areas, and therefore achieves maximum short-term profits to the recreation and tourism industry. These measures would be undertaken regardless of environmental effects: for example, there would be no concern for remedial work or conservation-related infrastructure (boardwalks, etc).

The sustainable tourism/environment/society mix (mix) This option essentially incorporates the items found in the Goulburn Broken Catchment Management Authority Upper Goulburn Recreational Waterway Strategy (http://www.gbcma.vic.gov.au/downloads/RegionalCatchmentStrategy_sub/RecreationalWaterwayStrategy_Final.pdf). The plan represents a more balanced approach to the concerns related to environmental, economic, and social issues.

6.2.2 *Management practices for different options*

An understanding of the aforementioned options can be aided by the following framework that describes the makeup of each option in terms of specific management practices (see table 1). For example, the current option has some elements of on-site management practices implemented, but none of those related to riparian-zone management or demand management.

On-site management In areas of minimum impact, these options can be used to good advantage. They can take the form of fences to keep people away from sensitive areas or to keep vehicles and horses out. Boardwalks and bridges have been used in many tourist sites to stop the impact of trampling (erosion) and driving (pollution). Provision of toilets can minimise the effects of wastes polluting sensitive areas (as well as improving aesthetic values).

The provision of toilets was noted as a key issue in the options workshop. Properly constructed car parks keep vehicles confined to nonsensitive areas and away from areas where erosion could be significant. Horse yards in areas that are popular for horse riding can limit the effects of trampling and grazing by unconstrained horses.

Table 1. Framework for options.

	Option [a]				
	current	max ES	max S	max Ec	mix
On-site management					
Fences	◐	●	◐	○	◐
Boardwalks	◐	●	◐	○	◐
Toilets	◐	●	◐	○	◐
Car parks	◐	●	◐	○	◐
Horse yards	◐	●	◐	○	◐
Weed control	◐	●	◐	○	◐
Riparian-zone management					
Fencing	○	●	○	○	◐
Demand management					
Scheduling, closures, etc	○	●	●	○	◐
Marketing	○	●	●	○	◐
Use of private land	○	●	●	○	◐
Signs/pamphlets, etc	○	●	○	○	◐

◐—some present; ○—not present; ●—present.
[a] max Es—maximise ecosystem services outcomes, max S—maximise social outcomes, max Ec—maximise economic outcomes, mix—sustainable tourism/environment/society mix.

Weed control is another on-site management activity. It should be noted, though, that these sorts of man-made solutions can decrease the visual or aesthetic appeal for some people.

Riparian-zone management The riparian zone is that area beside the waterway that is essential to the health of the waterway. Correct management of the riparian zone can be crucial to the health of the waterway. It is also essential for the provision of shade. Riparian-zone management can take the form of restricting access to these zones—usually by fencing. Again, these sorts of interventions can decrease the aesthetic appeal.

Demand management Marketing programmes may be very effective. Such activities could include: targeting marketing to some more sustainable recreation activities; scheduling and closures of sites and limiting numbers at peak times; user charges to limit numbers and to fund programmes; the use of private land where appropriate to alleviate the 'traffic' on public land; and targeting education, which can, over the long term, have significant impacts. This could include on-site education with pamphlets and signs to encourage users to take rubbish away, to keep out of certain areas, and not to take firewood, etc.

6.3 Criteria of assessment (section 5.3)

The options workshop also helped to identify the relevant assessment criteria. The criteria were grouped under three broad headings to reflect the desire for integrated and sustainable development in the catchment.

6.3.1. *Ecosystem services criteria*

The emphasis of the project was the study of the influence of ecosystem services in the decisionmaking process, and so all of the potential environmental criteria involved were ecosystem services. The ecosystem services criteria are described as follows:

Maintaining water quality This refers to the maintenance of the natural purity of the water, and is measured by the quantity of phosphorus (P) present in the water, in milligrams per litre.

Maintaining water quantity Preserving the natural flow of the water is important for downstream users, and is measured by means of a discharge indicator, in thousands of megalitres.

Preserving biodiversity/native biota Biodiversity (biological diversity) is perhaps most commonly defined as 'the full variety of life on Earth'. A qualitative indicator, where 10 signifies high biodiversity and 1, low, is used.

Soil maintenance through sediment filtration/retention This refers to the maintenance of soil and water quality through the filtering of sediments and the enhancement of soil stability. This is closely linked to vegetation cover. A qualitative indicator, where 10 signifies high sediment filtration and 1, low, is used.

Erosion control This can include the prevention of loss of soil by wind, runoff, or other processes and the storage of silt in lakes and wetlands. A qualitative indicator, from 10 to 1, is used to measure erosion control, as defined above.

Nutrient management/waste assimilation This includes storage, internal cycling, and processing and acquisition of nutrients, for example, nitrogen fixation. A qualitative indicator, from 10 to 1, is used.

Shading The provision of shade and shelter is closely related to vegetation and, therefore, biodiversity. A qualitative indicator, from 10 to 1, is used to measure shading.

Stream health, including instream and riparian zones This is dependent on the level of aquatic life, the vegetation quality, stream physical form, stream flow, and water quality. Here the index of stream conditions (ISC) is used to measure stream health (see http://www.vicwaterdata.net/isc/info1.html).

Aesthetics/scenic views This refers to the level of satisfaction derived from the visual appearance of the landscape. Aesthetic appeal is personal. Often, any intervention that takes a landscape away from its natural state may be regarded as diminishing the aesthetic appeal of that area or landscape. Such interventions may, for example, include roads, signs, boardwalks, weeds, and vehicles. However, some of these items may also be necessary to stop the landscape from deteriorating. Also, some people may regard diversity in the landscape as important and so a mix of native and agricultural land uses may be aesthetically appealing. Again a qualitative indicator (from 10 to 1) is used to measure aesthetic appeal.

6.3.2 *Social/cultural criteria*

The social and cultural criteria that were considered as being important in the decisionmaking process on an option for recreation and tourism in the catchment were as follows.

Public access This includes the number of people that are allowed to visit a site, as well as the means by which they can visit. Here, an indicator of 10 for high public access and 1 for low public access is used.

Jobs The level of full-time and part-time employment that a particular scenario may involve defines this criterion. This is measured by the total number of people employed.

Maintenance of cultural and heritage values Here, the provision of measures that will maintain the integrity of sites of cultural and heritage significance is referred to. A qualitative binary indicator is used to measure this, with a 0 indicating that the cultural and heritage values are not maintained and 1 indicating that they are.

Education The provision of educational campaigns can assist in the maintenance of sites; it is measured qualitatively with 0 for not present and 1 for presence of an educational campaign.

6.3.3 *Economic criteria*

The economic criteria used in the decisionmaking process were limited to those that could be readily measured from existing data.

Costs These are the monetary costs (both direct and indirect, to individuals and governments in the region) involved in the particular scenario. These can involve costs of establishing facilities at sites, weed control, fencing, lost incomes, etc. These costs are measured in AUS $.

Benefits These are the monetary benefits (both direct and indirect) involved in the particular scenario. They may be benefits from increased incomes of tourist operators, accommodation providers, etc. These are also measured in AUS $.

6.4 Ranking the criteria by relative importance (section 5.4)

The questionnaire revealed (figure 3) that the ranks of some of the criteria varied widely across the different stakeholders. For those criteria where there were wide disparities, expert witnesses were asked to provide information and to answer questions on the day of the jury.

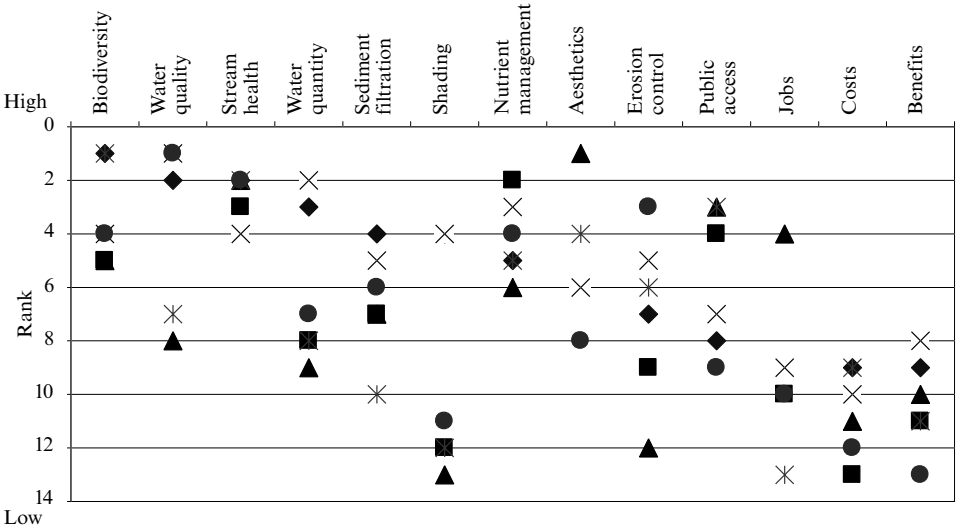

Figure 3. Ranking of the criteria by their importance, where each symbol represents the ranking of one of the six jurors.

6.5 Assessment of the options and the impact matrix (section 5.5)

An impact matrix, showing the values of each of the different criteria under each of the different options, was completed with the aid of expert input from various organisations (table 2, over). These experts were from state natural resource and forestry-management organisations, regional water-management organisations, and included CSIRO ecologists, private consultants who had carried out research in the regions, and reports that were relevant to the information required. The matrix included both qualitative and quantative indicators, as well as ranges for some indicators which were uncertain.

Table 2. Impact matrix.

Criterion	Indicator	Ecosystem service scenario [a]				
		current	max ES	max S	max Ec	Mix
Ecosystem services						
Water quality	Mg/l P	0.02	0.005	0.05	0.1	0.01
Water quantity	discharge 10^3 ml	150	250	100	125	150
Biodiversity/native biota	10 = high 1 = low	6	10	3	5	10
Sediment filtration	10 = high 1 = low	3	8	6	8	8
Erosion control	10 = high 1 = low	7	10	7	4	7
Nutrient management/waste assimilation	10 = high 1 = low	3	8	7	3	8
Shading	10 = high 1 = low	5	10	6	2	8
Stream health, including instream and riparian zones	ISC [b] very poor: 0–19 poor: 20–25 moderate: 26–34 good: 35–41 very good: 42–50	35–41	42–50	35–41	26–34	35–41
Aesthetic/scenic views	10 = high 1 = low	5	8	6	2	7
Social/cultural						
Public access	10 = high 1 = low	5	1	7	10	5
Jobs	number (thousands)	15	18	20	25	18
Cultural and heritage [c]	0 = not maintained 1 = maintained	0	1	1	0	1
Education [c]	0 = not present 1 = present	0	0	1	0	1
Economic						
Costs	AUS $ million	2.5–3.5	0	2.5–3.5	0	18.3
Benefits	AUS $ million	5.5–6.5	0	6.4–49	4.3–40.1	9–57.3

[a] max ES—maximise ecosystem service outcomes, max S—maximise social outcomes, max Ec—maximise economic outcomes, mix—sustainable tourism/environment/society mix.

[b] ISC—index of stream condition (see http://www.vicwaterdata.net/isc/into.html).

[c] These were added after the initial ranking process at the request of one of the jurors.

6.6 Aggregation and sensitivity analysis (sections 5.6 and 5.7)

The criteria were aggregated with the software ProDecX, using the assessment from table 2 and the rankings from figure 3. As the rankings provided only ordinal information, in order to use them in the numerical aggregation they had to be translated to a cardinal scale. It was assumed that the highest rank corresponds to a weight of 1/2, the second to 1/4, the third highest to 1/8, and the nth highest to $1/2^n$. This is analogous to the scale deduced by Janssen et al (1990).

From section 6.3 it can be seen that the number of ecological criteria is considerably greater than that of the other criteria. This reflects the concerns of the stakeholders well, but may—as turned out later in the stakeholder jury (section 6.7.1)—lead to

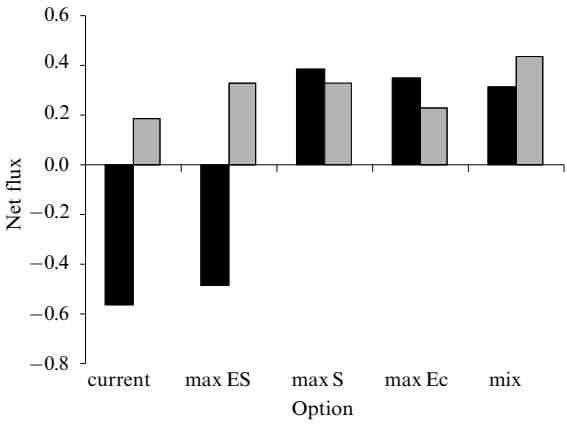

Figure 4. Means (black bars) and standard deviations (grey bars) of the net fluxes of the five options prior to the jury.

double counting (see section 5.3) and an unwanted bias—in the present case towards the option max ES. Different alternatives of feeding the ranks from figure 3 into the aggregation procedure were tested, and the most intuitive way to correct for the bias was to rescale the weights such that the sum of the weights of the ecological criteria was 1/3, and this was equal to the sum of the weights of the social as well as the ecological criteria. The result (figure 4) was presented and discussed in the stakeholder jury (see below).

6.7 The stakeholder jury: procedure and results

The jury was asked to consider the information presented to them (in the impact matrix, and by the expert witnesses selected by the authors) in a facilitated and deliberative process.[5] Their charge was to come to a unanimous decision with respect to a set of weightings for the assessment criteria. This was to be done after more information on various criteria had been provided by the expert witnesses. The decision process, including the effect of a set of weightings on the final ranking of the recreation and tourism options, was aided by interactive use of the ProDecX software. The day was split into two sessions: the morning session, with expert presentations and discussions as well as the opening of the second iteration of the decision process (see figure 2); and the afternoon session, with iterations of criteria weighting, software interaction, and deliberation.

6.7.1 *The morning*

The day started with descriptions of the process, the charge, and the software to be used. An overview of jurors' priorities was provided from the results of the questionnaire which had been distributed some weeks prior to jury day (figure 3). In the figure, each symbol represents the priorities of one of the six jurors, from 1 for the highest ranked criterion to 13 for the lowest. The figure shows that there are considerable differences in the ranking of the priorities for certain criteria. For example, it can be seen that the criterion erosion control differed in priority from third to twelfth place for different jurors. Also, the results of the ProDecX run (using the weightings of all jurors from figure 3 and aggregating them according to sections 5.6 and 6.6) were shown to the jurors. These indicated a top ranking for the maximise social outcomes (max S)

[5] The 'judge' was Dr Gail Kelly, a Community Psychologist from CSIRO with many years experience in the research and facilitation of processes involving public participation and environmental issues.

option (figure 4), as it had the highest average net flux. The next best options were maximise economic outcomes (max Ec), sustainable mix (mix), maximise ecosystem services (max ES), and last, business as usual (current). This caused some amount of concern to the jury as the sustainable mix option (ranked third in the initial ProDecX run) is, in fact, the strategy which is about to be implemented in the catchment and which is supported by the organisations that were represented by the jury members. The low ranking of the sustainable mix option could indicate that it is lacking in the delivery of some outcomes ranked highly by the jury. An important observation is that in the three best options—max S, max Ec, and mix—the uncertainty, that is, the standard deviation of the net flux, was much larger than the differences between the average net fluxes. This indicates that dissent on the criteria weights was so high that a conclusive ranking was not possible, that is, no consensus on the relative ranking of these three options was achieved. Only the two worst options, max ES and current, had such small average net fluxes that they were clearly outperformed by the three best options. An objective of the jury was then to improve consensus on the weights and come to a more conclusive ranking of the options.

The jurors were asked to decide whether the three broad categories of criteria (the ecosystem services, the economic, and the social and cultural groups) should be weighted equally to allow for the larger number of ecosystem services criteria compared with the other criteria groups, as had already been proposed (section 6.6). After some discussion, all agreed that such a broad weighting would reflect the desire for sustainable development in the region. Also, at the request of one of the jurors, two additional criteria were added and assessed by the experts (see sections 5.3 and 5.5, second iteration of the process) in the social and cultural category: the maintenance of cultural and heritage values, and the provision of education. The first expert witness to be called was from the local water authority and gave an overview of water-quality and water-quantity issues relevant to the consideration of different recreation and tourism options. The issues covered included the status of storage dams; cumulative effects; and the effects of different types of recreation and tourism on water quality, water quantity, and monitoring. A great deal of discussion followed, and questions from the jurors centred around the adequacy of monitoring, lessons learned from overseas experiences, and whether or not education of tourists would be effective in maintaining water quality.

The next expert witness was the environmental manager from a local ski resort who spoke on public access and aesthetics. His talk highlighted issues such as sense of place, cultural identity, the importance of life-fulfilling ecosystem services, the cultural icons of mountains, and the injection of money into the local economy as a result of these aspects. The discussion afterwards centred around the positive effects of restricting public access, such as environmental preservation, and also the issue of open access leading to increased knowledge of the public about environmental issues. Discussion also highlighted certain user groups which were causing considerable environmental damage—for example, four-wheel drive vehicles, motorbikes, horses, and campers—and whether these groups should have their access restricted. One idea that was proposed was to encourage tour groups to educate people on the effects of tourism on the environment. One way of doing this would be to introduce a code of practice for tour operators to agree to.

The third witness, from a state natural resource management authority, discussed issues concerning soil erosion. These included the fact that road usage determines sediment-production rates, where 90% of sediment runoff comes from roads and depends on the surfaces, age of the road, soil type, etc. The removal of vegetation from riparian zones also affects soil erosion. Horses and off-road vehicles can be

damaging users, and the best management practices available to stem these effects include culverts and road surfacing. The total numbers of vehicles and horses, as well as points of access (for example, to streams), were also key considerations. An important point that was raised concerned the current lack of sufficient resources with which to manage these problems. One possible solution discussed was a levy on users in high-damage categories (for example, four-wheel drive vehicles). It was considered however, that political will was a fundamental requirement for the imposition of such measures, and that more research into providing incentives for solutions from markets and private firms was required.

The fourth expert, a member of the local parliamentary council, presented information on jobs and economic issues. He spoke of the bonuses to local jobs and industry resulting from recreation and tourism activities. Again, the discussion reverted to public access issues, the management of numbers, and whether lessons could be learnt from other experiences with 'user pays' schemes. Also identified was a need to measure the effects of public access on the riparian zones adjacent to rivers and streams (which, in turn, requires an exact definition of the extent of this zone). One question raised was that of whether it is possible to engage private landholders in recreation and tourism activities and, if so, whether this would provide the experiences required by the public. In addition, the jury also agreed that the multiplicity of public land managers needs to be limited in some way.

After the expert presentations and questions and discussions, the jury was asked to provide a weighting (as opposed to just a ranking) of the various assessment criteria to reflect each individual juror's priorities (section 5.4, second iteration). Each juror was given one hundred cannelini beans each, and they agreed that one third of the beans should be divided among the ecosystem services criteria, one third among the social and cultural criteria, and one third among the economic criteria. After the weighting exercise, the jurors and expert witnesses took part in informal discussions over lunch.

6.7.2 *The afternoon*

The resulting criteria weights were fed into ProDecX and also graphed on a whiteboard so that all jurors could see each other's positions (section 5.6, second iteration). The initial discussions revealed that the nine ecosystem services criteria could be limited to only four (water quality, water quantity, biodiversity, and aesthetics) as these were all that were needed for the jurors to make decisions on recreation and tourism options (section 5.3, third iteration). They argued that biodiversity, water quality, and water quantity influence stream health, in that higher levels will be directly associated with better stream health. Biodiversity and vegetation cover also influence shading, because more biodiversity and vegetation cover (which are themselves closely related) will be directly measured as increased levels of shading. Similarly, higher levels of erosion control, sediment filtration, and nutrient management will mean better water quality. Therefore, the nine ecosystem services criteria can be adequately covered by just four: water quality, water quantity, biodiversity, and aesthetics (figure 5, over). The other criteria were deemed redundant as separate decision criteria for the decision problem under review.

After the reassessment of the necessary ecosystem services criteria, the weighting exercise was again carried out and the results graphed on the whiteboard (section 5.4, third iteration). Each broad criteria group was then discussed, one at a time, outliers identified, and jurors asked to defend their positions and to indicate whether they would vary them or not (section 5.4, further iterations). For example, one of the jurors had a value almost twice that of the others jurors' priorities for the criterion public access. That juror was then asked to defend why he or she had placed such a

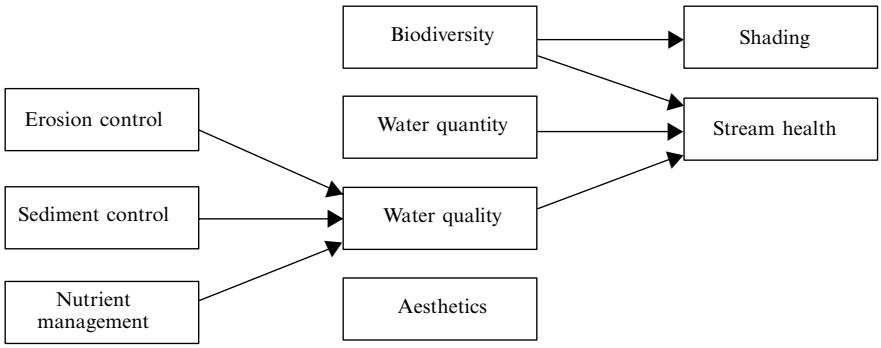

Figure 5. Causal links defined by the jurors between various ecosystem services criteria.

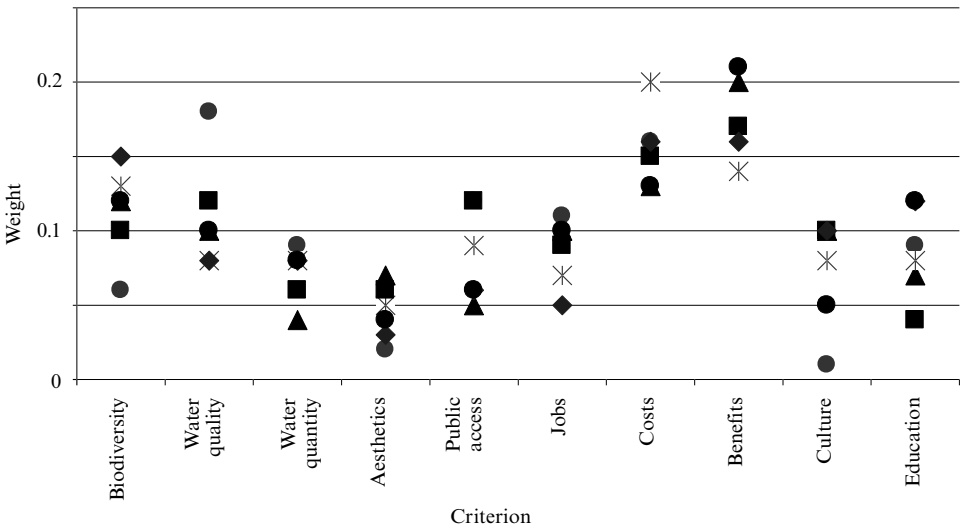

Figure 6. Weighting of criteria where each symbol represents the weighting of one of the six (for each juror normalised to a sum of one).

significantly higher priority on public access than the other jurors. After some discussion, that juror decided that he or she had neglected some of the important points raised by the other jurors and had overestimated this priority—and was willing to revise it. As soon as a final position was agreed (a situation where no one was prepared to alter their individual weightings any further, see figure 6), the weightings were fed into ProDecX (section 5.6, final iteration). The resulting outcome was the mix option with the highest average net flux. It can also be seen from figure 7 that the uncertainty (standard deviation) in the net fluxes had decreased considerably (compare with figure 4), indicating that the ranking was now much more conclusive and consensus much higher than before the start of the process.

7 Sensitivity analysis and discussion (section 5.7, final iteration)

A detailed sensitivity analysis was carried out after the jury process to assess the decision problem further. First, the broad group weightings (agreed to by the jury to be 33% for the ecosystem services criteria, 33% for the social criteria, and 33% for the economic criteria) were systematically varied. In the first instance, a group weighting of 40% was given to the ecosystem services criteria and the others were

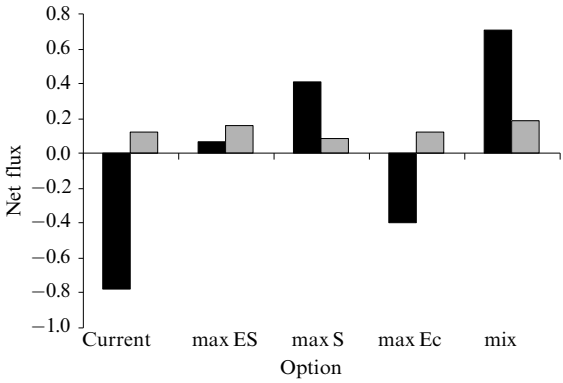

Figure 7. Means (black bars) and standard deviations (grey bars) of the net fluxes of the five options after the jury

set at 30% each. None of the permutations of different group weightings made any difference to the overall rankings of the options. Next, some of the outliers found in the final weightings of the criteria were, in turn, fed into ProDecX. The first to be used (keeping all other weightings consistent with the final agreed values) was the high weight of 0.18 for water quality; then the low outlier of 0.06, for biodiversity, and then the 0.20 outlier for monetary costs were used. These tests also did not alter the overall ranking of the options.

An analysis of the changes in the rankings of options after the jury process did reveal some important aspects of the procedure. Before the jury met, use of a straightforward qualitative *ranking* (from a high rank of 1 to a low rank of 13) of the criteria resulted in an overall outcome of the max S option being ranked first, max Ec second, and the mix option third. The next run of the ProDecX software was done after quantitative *weightings* of the criteria had been undertaken (distributing 100 beans among the various criteria) and also after the expert witness had given their presentations. Furthermore, the jurors were asked to give the whole of the ecosystem services criteria the same total weight as the whole of the social, and the economic criteria (that is, 1/3 for each criteria group) whereas in the first iteration this had been considered through an a posteriori rescaling of the weights from figure 3. The main changes in the rankings of the options that occurred were a greatly worsened rank for the max Ec option, and a greatly improved position for the max ES option. Because of the various changes in the procedure before this step, it is difficult to attribute causes to these different rankings (for example, the effect of the expert presentations). The largest change to the overall rankings came when some of the ecosystem services criteria were dropped. This resulted in the mix option being ranked first, followed by the max S, and then the max ES options. Even after going through each set of criteria in turn to try and reach, as far as possible, a consensus on the weights, the overall rankings of the options did not alter very much. The difference that was made was that the uncertainty measures were reduced and the probability of that particular rank order occurring, therefore, were much higher.

These findings mean that, in this particular instance, obtaining *exact* consensus on the weights of the criteria was not important as some variation in the weights (for each criterion) was tolerable to obtain consensus on a preferred option. However, of crucial importance was the process of each person defending his or her criteria weightings—because of the important information that was revealed. For example, because of this process, jurors could in turn bring out the main issues that were important to them in choosing a criterion weight and, as it turned out, some of these legitimate issues had

not been considered by some of the other jurors. Also, from the findings, a critical part of the process was the determination of the exact criteria to be considered, and this occurred only after a significant amount of discussion, by the jurors and experts, that led ultimately to the simplification and nonduplication of the various decision criteria.

8 Conclusions

In this paper we have introduced some advantages and disadvantages of two decision-aiding techniques and have 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 were applied to a case study identifying and prioritising ecosystem services in the Goulburn – Broken Catchment of Victoria, Australia. In this application it was shown how the advantages of multicriteria evaluation, in providing structure and integration in complex decision problems, was combined with the advantages of deliberation and stakeholder interaction provided by a citizens' jury.

An important characteristic of the process was the iteration of phases of deliberation and of the steps of the MCE. Not every step of the evaluation shown in figure 2 has, necessarily, to be carried out in each iteration, but it is left to the jury as a whole to steer the process and to decide which operation to perform next.

The deliberative MCE of recreation and tourism options in the upper Goulburn – Broken Catchment highlighted the fact that continuing with the current regime of recreation and tourism strategies was not an appropriate option. The process did support a change to the mix strategy, but emphasised the need for greater research on public access issues, the effects of education on tourists and environmental damage, methods for the recovery of management costs, and the role of market and other incentives in limiting the environmental damage caused by recreation and tourism activities. The mix option is to be implemented, and no doubt would have been anyway, regardless of the outcome of the stakeholder jury, but the process pointed out the issues listed above that need greater investigation in order for this option to reach its objectives.

The exercise also identified some aspects of the procedure itself which could be improved upon, such as the need for greater discussion of the steps in the process at the start and more explanation of the criteria and the impact matrix. Comments were received from the jurors on their assessment of the process at its completion, and they were questioned about whether or not it would be suitable for lay people—given the complexity of the issues involved and the short time frame allowed for the jury procedure. The jurors in this case had two days of face-to-face discussion (the first day involved the identification of issues and from those the relevant options, objectives, and criteria; and the second day involved the deliberative process) but in between these face-to-face sessions the jurors had involvement with the issues through the larger Ecosystem Services Project meetings as well as information exchange via e-mail. Such a process involving citizens would have to allow for a longer time frame for participants to understand the complex issues, as well as the practicalities of the procedure itself, and to engage in longer deliberations as required.

Although the software in its present version allowed for the simultaneous consideration of several decisionmakers, the input of multiple weightings turned out to be cumbersome as the weights had to be entered separately for each juror. Moreover, it was not possible to show the weightings of all jurors at once on a single screen. As the jurors felt this necessary, in the present study a white board had to be used for depiction and adjustment of weights—which were then copied into the software by the analyst. This slowed down, and partly obstructed, the real-time interaction between

jurors, analyst, and software, such that a full MCE could be carried out only at the beginning and at the end of the process. This deficiency is currently being remedied, so that the weights of all decisionmakers can be presented and edited on a single screen and the software will allow for fully interactive manipulation of multiple weightings, as well as convenient and fast sensitivity analyses. The jurors themselves, however, did not mention difficulties in understanding the software as hindering their participation in the jury process. Another issue that could be addressed in future applications of the deliberative MCE process is the need for consistent weighting procedures before and after the expert witnesses' presentations so that the effectiveness of these in the process can be properly assessed.

In conclusion, the process identified to the jurors the importance of breaking down the decision problem and consequently being able to seek the correct information to try and solve the problem. This involves asking the right questions at the start of the process, and for researchers to know the priorities of the decisionmaking criteria and which of those criteria are important to measure. On the whole, the jurors found the process interesting, enlightening, and enjoyable, with the highlight for most of them being the revelation of different jurors' priorities and their defence of these positions.

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