GROUP DECISION SUPPORT METHODS TO FACILITATE PARTICIPATIVE WATER RESOURCE MANAGEMENT

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Group Decision Support Methods to Facilitate Participative Water Resource Management

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Glossary

Attribute	A characteristic of a scenario.
Criterion	A particular point of view or interest according to which policy or decision alternatives may be compared. This may be an implicit or explicit function of one or more attributes.
Scenario	a hypothetical alternative
Value tree	a hierarchical structure of criteria grouped into categories of similar criteria or criteria which contribute to the same objective.

Acronyms

CMA	Catchment management agency
CMS	Catchment management strategy
CSIR	Council for Scientific and Industrial Research
DM	Decision Maker
DSS	Decision Support System
INR	Institute of Natural Resources, University of Natal
MCDA	Multi-Criteria Decision Analysis (or Aid). Equivalent to MCDM (MCD Methods) in other literature.
NPV	Net Present Value
NWA	National Water Act (Act 36 of 1998)
SBPP	Scenario Based Policy Planning
SMART	Simple Multi-Attribute Rating Technique
SEA	Strategic Environmental Assessment
SFRA	StreamFlow Reduction Activities
VISA	Visual Interactive Sensitivity Analysis

Executive Summary

In previous WRC-funded projects, the decision analysis group in the Department of Statistical Sciences at the University of Cape Town has developed the concept of *Scenario Based Policy Planning (SBPP)* for use in the evaluation of strategic alternatives within any public sector planning context but in particular for water resources planning. The key features of SBPP are the following:

- The systematic generation of a relatively small number of scenarios (not in the sense of 'external' scenarios such as different population growths, but in the sense of hypothetical alternatives) to present the range of available strategic options. These scenarios are defined to a requisite level of detail to allow different stakeholders groups to identify a clear preference ordering amongst the alternatives, but no more detail than is necessary for this purpose.
- The use of tools from *Multiple Criteria Decision Analysis (MCDA)* to assist stakeholder or interest groups to formulate their preferences: The first step is to assist the group in structuring their evaluation in terms of a "value tree", i.e. the criteria against which alternatives should be assessed. The options are then evaluated initially against each criterion individually, after which the evaluations are aggregated into an overall preference ordering. In practice, we have recommended the use of *value measurement theory* for the evaluation step, primarily because it provides a common currency for comparing the preferences of different groups. In brief, value measurement theory involves a process of scoring options initially against the most basic criteria within which there is little conflict or ambiguity, and then gradually aggregating these scores across more-and-more divergent concerns and interests.
- Comparison of the MCDA outputs from each group in order to identify potential consensus solutions: These outputs provide a mechanism for communication of value judgements and preferences between different groups, and between the groups and policy makers. The resulting information can be used to identify (a) alternatives which are clearly not viable; (b) alternatives which are potentially good compromises between conflicting goals, but in need of specification to greater levels of detail before a final choice can be made; or (c) new alternatives consisting of combinations of features from the alternatives which have been evaluated. This process may be carried out in group discussion, possibly facilitated by other techniques of MCDA.
- Iterative process: SBPP is intrinsically iterative. After one pass through the above process, the surviving policy options may need to be refined and/or supplemented by additional options, after which the process repeats until there is acceptance that the best consensus has been achieved.

The concepts of SBPP and MCDA have been detailed in previous WRC reports (WRC 296/1/93 and WRC 512/1/97), and are summarised together with some updated concepts in Chapter 2 and Chapter 3 of the current report.

Links to National Water and other Acts

The original development of the SBPP/MCDA procedures were motivated by a realization that strategic decision-making must involve all stakeholders effectively from an early stage of planning. This was recognized as good practice, even though there was at that time little in the way of legislative requirement for involvement of stakeholders in policy formulation and decision processes. More recently, however, the promulgation of the National Water Act of 1998 has both recognized the existing of many potentially conflicting criteria in water resources planning, and mandated the effective involvement of different stakeholders in the process (especially through catchment management

agencies or CMAs). The development of the SBPP and related MCDA concepts has thus anticipated the requirements of the new act, and provides a mechanism whereby the intentions of the act can be realized. A detailed comparison is made in the report of the links between SBPP/MCDA and not only the new National Water Act, but also related legislation such as the National Environmental Management Act, the Environment Conservation Act and the National Forests Act. Within the context of the National Water Act, it is argued that the SBPP/MCDA process is directly relevant to the determination of management classes, the determination of reserve for basic human and ecosystem needs, the determination of resource quality objectives and the formulation of catchment management strategies and water allocation.

Conclusions reached from this evaluation of the requirements of the various acts in the light of the SBPP/MCDA process are the following:

- SBPP/MCDA offers a theoretically sound and broadly accessible framework for developing and evaluating alternatives as required by the acts;
- MCDA offers tools with which to define criteria contributing to the overall objectives against which the alternatives can be evaluated;
- MCDA provides the opportunity to include a wide range of inputs (qualitative and quantitative), from different stakeholders, helping to ensure the holistic and transparent assessment which appears to be the intention of the acts;
- MCDA offers a means for developing coherent and justifiable scoring systems for indices, to be used in determining priorities.

Case Studies and Action Research

Much of the research documented in the present report can be classified as "action research". The research team became intimately involved in a number of case studies, in many cases taking the initiative in organizing the group forums and discussions, and coordinating the data collection where necessary. Case studies reported in the main report are the following:

(1) **Sand River project**: This was run as a pilot project, commissioned by DWAF, to investigate approaches to catchment planning within an integrated catchment management framework. Our involvement related to the implementation of MCDA in evaluating land-use alternatives (scenarios in our terminology) and their associated water-use implications. Four workshops were conducted, during which impacts on ecological, social and economic issues were evaluated using the "thermometer scale" techniques of value measurement. Our group also needed to take responsibility for the development of a data base to support the evaluations. The overall recommendations are being carried through to a phase II of the project.

(2) **Land-use and forestry in the Maclear district**: Some of the initial work on this project was reported in the report WRC 512/1/97. Following on from a WWF-funded project on classifying ecosystems in the region, a series of four workshops were held with representatives of a variety of interests, including conservation, the forestry industry, and local political leadership. The aim was to establish some consensus concerning appropriate levels of afforestation in the region. In many senses, our group needed to take responsibility for arranging and facilitating the workshops and assembling the relevant data. Clear recommendations did emerge from the final workshop, and have been conveyed to the Forestry Review Panel. Final decisions have not been made, and further environmental impact assessments have been commissioned.

(3) **Baviaanskloof Wilderness Area**: This work arose from a proposal by Eastern Cape Nature Conservation to expand the Baviaanskloof Wilderness Area. The SBPP/MCDA approach was

used to provide inputs into the evaluation of different scenarios which might result from the proposal, in terms of direct, indirect and non-use values. Once again, our inputs involved the use of SBPP/MCDA within a workshop setting, as well as collating information into the required data base. At this stage, a preliminary ranking of alternatives has been developed and provided to the main participants. Further evaluation of conservation impacts is being undertaken as part of a WWF-funded project.

(4) **Classification of Estuaries**: This exercise differed from the previous three, in that the MCDA procedures were used not to assess policy scenarios directly, but to develop indices for classifying estuaries into management classes, taking into consideration a number of divergent criteria. Part of this exercise involved the use of questionnaires rather than workshops. Contributions emerging from this study are included in the DWAF Resource Directed Measures initiative.

The primary purpose of involvement in the above case studies was to develop an understanding of the dynamics of implementation of SBPP/MCDA in practice. For this reason, it is important to focus on the lessons which can be extracted from the experiences (see next section), and which provide guidelines for the wider implementation of the processes. A brief survey of key participants in some of the case studies indicated that almost all participants found the process itself useful, especially in terms of the holistic integration of the different views provided, while the majority found the basic tools easy to understand. There were some who found certain of the more intricate tools (such as the sensitivity analyses) less easy to understand, and this clearly needs to be addressed in the introductory courses on SBPP/MCDA which are planned for presentation in the next months.

Principles arising from case studies

As indicated in the previous paragraph, an important part of the research was to document the key lessons for implementation of SBPP/MCDA for water resources planning in South Africa that can be extracted from the case studies. These are as follows.

(1) *Role of the facilitator / decision analyst*: The decision analysts cannot simply be neutral advisors or meeting facilitators, but need to become an integral part of the project team. The experience from the case studies was that the decision analysis team had an important role to play in interpreting user inputs, in identifying information needs (see next point), and in coordinating data collection and collation.

(2) *Discipline of the MCDA process in identifying critical information needs*: The systematic process of evaluation of alternatives in terms of identified criteria, coupled to sensitivity analyses reveals clearly what additional information or quantitative data is or is not important to reaching a justifiable and robust solution.

(3) *Consistency checks and feedback to participants*: The MCDA process requires participants to express many value judgements in sometimes quite qualitative and intuitive terms. It is important that the implications of these judgements be fed back to the groups, in terms, for example, of implied trade-offs (such as implied monetary equivalents of social and environmental goals). This is easily incorporated in to the process, and provides participants with a global sense of whether the results are consistent and justifiable. The key point is that while the theoretical foundations of MCDA in general, and value measurement in particular, provide justification for the procedural rationality of the process, it is these consistency checks which provide the basis for claiming substantive rationality, i.e. that the conclusions themselves have validity.

(4) *Allowance of adequate time for the process*: By definition, we are dealing here with complex strategic decisions. Although the SBPP/MCDA process can facilitate the process, making it both

effective and efficient in communicating values between interest groups, there is still time needed to allow all participants to develop and to share insights, and to establish relevant information needs. The experience from the case studies suggests that for non-trivial problems it would be expected that four or more workshop sessions are typically needed, separated by periods of data gathering and reflection.

(5) *Use of appropriate technology*: The process is best supported by some form of decision analysis software (see next section), particularly to allow for rapid feedback of sensitivity analyses and consistency checks. On the other hand, not all participants may be comfortable with direct use of computer tools, and there may be advantages in using "pencil-and-paper" or flip-chart processes in the workshop, with an analyst present to capture the results electronically. One possibility to be investigated within the follow-up project is the extent to which internet-based systems may be advantageous, allowing users to experiment with inputs in their own environment which may be less threatening than in an open workshop.

Software support

One of the objectives of this research project was to evaluate and to develop where necessary the appropriate decision support software to implement the SBPP/MCDA process.

The general experience has been that the commercially available V·I·S·A software provides almost all of the support needs for use in workshops and for extensive analysis between workshops. Some possible extensions may be improved links to spreadsheet models, and to GIS systems.

The project leader collaborated with the Institute for Environmental Studies at the Free University of Amsterdam, on the development of a multi-criteria decision support system for use in environmental impact assessments. The intention of this system is to allow specialist groups representing different interests to carry out evaluations at their own time and place. This software is being released in The Netherlands under the name "DEFINITE for Windows", and may be useful for the same purpose here.

As previously indicated, there may be advantages in an internet-based support system, and a first experimental version of such software has been developed and is under testing. This development will continue in a follow-up project.

Recommendations for further research

The results of the research reported here have clearly demonstrated both the viability and the value of the SBPP/MCDA procedures for a variety of water resource planning problems. The following needs for additional research have nevertheless been identified:

- Effective means of integrating the SBPP/MCDA procedures into the regular operational activities of catchment management agencies and other groups concerned with assessing and recommending flow requirements and management plans.
- Full development and implementation testing of internet-based software support systems, as described in Chapter 10.
- The effective integration of spreadsheet, GIS and other data management systems into the MCDA software.

Chapter 1. Introduction

The decision analysis group in the Department of Statistical Sciences at the University of Cape Town, has, together with this report, completed three WRC projects related to water resource management and decision-aid. The first project (Stewart *et al.*, 1993) assessed and discussed multi-criteria decision support methods used elsewhere in the world, and developed a new concept of Scenario Based Policy Planning (SBPP) linked to established concepts of multi-criteria decision analysis (MCDA). Through application in further real-world studies, the next report (Stewart *et al.*, 1997) examined the practicalities of the combined SBPP/MCDA approach, in particular in comparison to cost-benefit analysis (CBA). This second report also explored the use of "soft" problem-structuring techniques, and the use of MCDA techniques in the formation of indices for prioritisation and classification.

The project reported upon here further expands on all of these themes, in particular with the view to making the approaches more accessible to users, placing the SBPP/MCDA approach in context with other (complementary or supplementary) decision support methods and providing practical guidance for application. The structure of the report is summarized in Figure 1.1, which also illustrates the links between the chapters. An indication is given as to which chapters can be read more-or-less on their own, and/or which can be skipped by readers only wishing to follow specific themes.

The initial background chapter (Chapter 2) is intended for the reader who desires a fuller understanding of the principles and methods of MCDA, and includes approaches other than those which are discussed in the remainder of the report. An overview of the full SBPP/MCDA process, in a relatively stand-alone format, is provided in Chapter 3, where SBPP/MCDA is presented in an easily accessible, step-wise approach, with the emphasis on practicalities. Where necessary, some reference is made to details found in Chapter 2 (e.g. possible questioning procedures which can be used to elicit weights), in order to avoid unnecessary duplication.

The next two chapters place the SBPP/MCDA approach in a contextual framework. Firstly, MCDA is linked to the requirements of various new environmental legislation, in particular the National Water Act (Chapter 4). Secondly, a number of other decision support tools which are available for various stages of decision making (e.g. SEA, CBA, OHP) are discussed and related to SBPP/MCDA (Chapter 5).

A number of chapters are then devoted to a series of case studies in which the procedures have been implemented. These case studies are briefly introduced in Chapter 6, together with a summary of lessons which have been extracted from them. The case studies themselves follow in Chapter 7 to Chapter 9.

Experiences from these case studies have led to the development of a web-based decision support system, which is designed to facilitate the implementation of the SBPP/MCDA approach for geographically dispersed stakeholders. The system described in Chapter 10 is still in a preliminary form, requiring further testing and refinement, which will continue as part of a follow-up project.

The overall conclusions which can be drawn from the research reported herein are set out in Chapter 12.

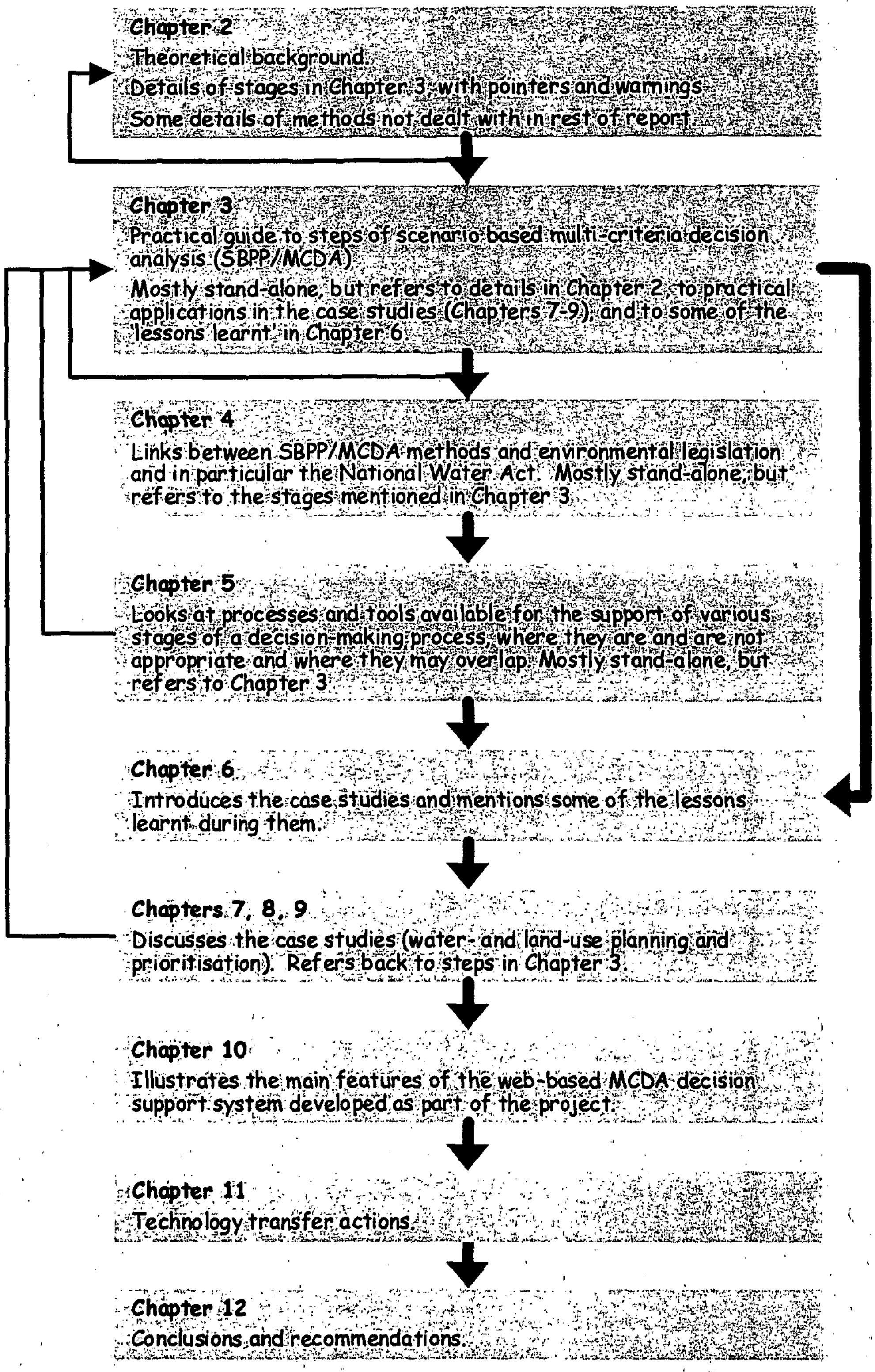

Figure 1.1. Layout of the report showing the links between different chapters.

Chapter 2. Multiple Criteria Decision Analysis in Water Resources Planning[1]

2.1 Formulation of planning and decision problems in multi-criteria terms

All non-trivial decision-making involves some measure of trade-off between conflicting goals or objectives, and this is particularly true for decisions in the public domain such as in water resources planning. All too often, the resolution of such conflicts is left to "gut-feel", or "seat of the pants" flying. We do not wish to undervalue the importance of management intuition in decision making, recognizing that public sector decision making is ultimately a political process. It must, nevertheless, be recognized that in a rapidly changing world, there is the potential for the experience on which the intuition is based to become rapidly outdated. Furthermore, even when the intuition is good, there is a need to be able to justify the decisions to all interested and affected parties. For these reasons, good planning practice should be supported by formal analysis of the decision options and their impacts on the relevant interests and societal goals. Such analysis is the aim of Multiple Criteria Decision Analysis (MCDA).

Most management science recognizes implicitly or explicitly the existence of multiple goals as indicated in the previous paragraph. The characterizing feature of MCDA is, however, the establishment of formal and to some extent quantified procedures for the following three phases of the problem:

(1) Identification of relevant criteria, i.e. points of view or axes of preference according to which possible courses of action can be distinguished;
(2) Ranking, or possibly more extensive evaluation, of alternative courses of action according to each identified criterion;
(3) Aggregation across criteria to establish an overall preference ranking for the alternatives.

It should be emphasized at this point that the above three phases are relevant at various levels of decision making. For example, a specific interest group (such as a group of small farmers) might go through these phases in order to establish their own preferences to be argued in a wider forum; or the government department responsible for water planning might need to go through a similar set of considerations in order to make and to justify proposals for strategic water development plans. MCDA might thus usefully be applied at these and many other levels, as discussed in Section 2.3. For the remainder of this Section, we shall expand slightly on the role of MCDA in the above three phases.

2.1.1 Criteria and Value Trees

The first step is to identify the criteria relevant to making the decision. A criterion is defined in this context as any concern, interest or point of view according to which alternative courses of action can (more-or-less) unambiguously be rank-ordered. Keeney and Raiffa (1976) suggested that in establishing a family of criteria for use in decision analysis, the following properties should be aimed at being:

[1] This chapter is taken from a document on multiple criteria decision analysis prepared for the World Commission on Dams.

- *Complete*: Ensure that all substantial interests are incorporated;
- *Operational*: Ensure that the criteria are meaningful and understandable to all role-players
- *Decomposable*: Ensure as far as is possible that the criteria are defined in such a way that meaningful rank orders of alternatives according to one criterion can be identified, without having to think about how well the alternatives perform according to other criteria. (The so-called condition of *preferential independence*.)
- *Non-redundant*: Avoid double-counting of issues
- *Minimum Size*: Try to use as few criteria as possible consistent with completeness, i.e. avoid introduction of many side issues which have little likelihood of substantially affecting the final decision.

A variety of brainstorming procedures can and have been used for the purpose of identifying the criteria relevant to a particular situation, taking the above considerations into account. A review of such procedures is beyond the scope of this paper, but it is worth mentioning the existence of software such as "Decision Explorer" and "GroupSystems" which can facilitate this process.

In most cases it is useful to structure the criteria into a hierarchical value tree, starting with a broad overall goal at the top, systematically broken down into increasingly precise sub-goals, until at the lowest level we have the required set of criteria as described above. Such a value tree is illustrated in Figure 2.1, which is based on experiences in applying MCDA to land-use and water resources planning in the eastern escarpment regions of South Africa. The criteria are the right-hand-most boxes, namely: household income, number of jobs, etc., down to flood levels.

The advantage of such a hierarchical structure is that the application of MCDA can be decomposed, for example by first evaluating alternatives within a subset of criteria (for example the three contributing to social benefits), and aggregating these to give a preference ordering according to "social" issues (thus forming a super-criterion). At a later stage, a further aggregation can combine social, economic and environmental concerns.

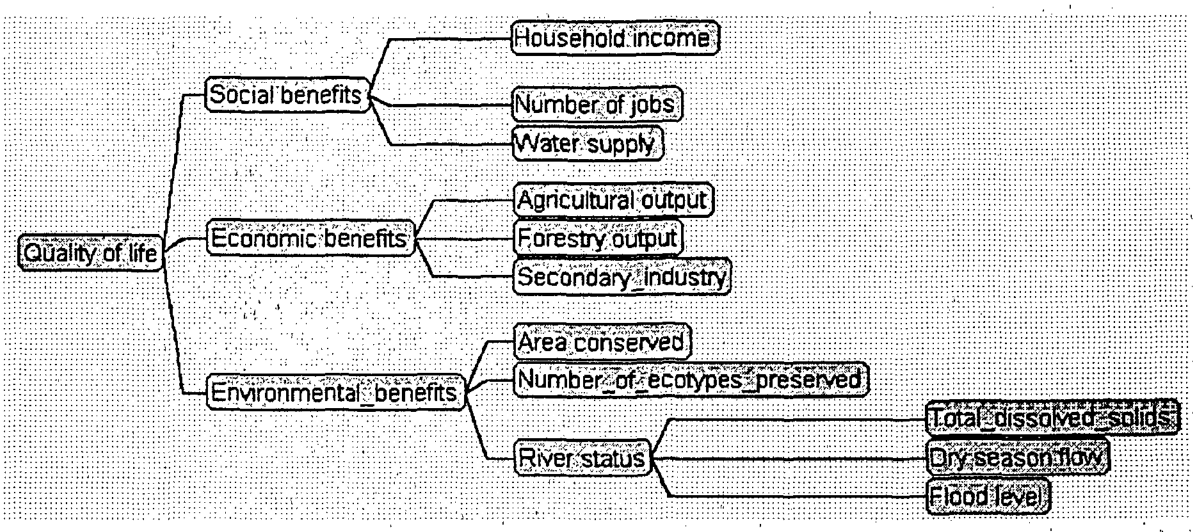

Figure 2.1. Illustration of a value tree.

The value tree can be structured from "top-down" or from "bottom-up". In the top-down approach, one starts by identifying broad concerns (such as social, economic and environmental). An attempt is made to rank order the alternative courses of action in terms of these. If this is achievable with little controversy, then the identified concerns are "criteria". If not, each is broken down further (as, for example, the division of social into employment, housing and services and personal well-being). Once again, we attempt to rank order the alternatives according to these issues, until such time as operational meaningful criteria are elicited. In the bottom-up approach, the first step would be to brainstorm all concerns which might influence preferences between all alternatives. These may then be clustered into groups representing similar higher level goals, eliminating any double-counting which may occur in the brainstorming process.

Although we have described the identification of criteria in terms of operationally meaningful rank-ordering of alternatives, Keeney (1992) has warned against an overly alternative-focussed mode of thinking, and proposes "value-focussed" thinking in its place. Taking a top-down approach, he urges that decision makers give consideration to the real values they wish to achieve, rather than purely considering the ranking of current alternatives "on the table". This is excellent advice, and is a spur to creative thinking towards the identification of new alternatives. It nevertheless remains true that the criteria need to be defined in such a way that the rank-ordering of all alternatives can be stated more-or-less unambiguously.

2.1.2 Within-criterion comparison of alternatives

At this stage, alternatives are compared and evaluated relative to each other in terms of each identified criterion. The alternatives may be real courses of action, or may be hypothetical constructs (performance categories as described below), built up to provide a set of benchmarks against which the real alternatives can be evaluated. In either case, however, the fundamental requirement is to be able to rank the alternatives from best to worst in terms of the criterion under consideration. If this cannot be done, then the definition of the criterion needs to be re-visited.

There is an important feature of this process, which is that it is carried out separately for each criterion, and does not need reduction to artificial measures such as monetary equivalents. All that is required is for the decision maker or interest group to be able to compare alternatives with each other in terms of their contribution to the goals represented by the criterion under consideration.

In some cases, criteria will be qualitative in nature (for example, a criterion such as "personal well-being"), so that the rank ordering will have to be subjective or judgmental in nature. For smaller numbers of alternatives (say up to about 7 or 9), this creates no problem as it will generally be possible compare alternatives directly to generate the required rank orderings or evaluations in an unambiguous manner. For larger numbers of alternatives, however, direct comparisons become more difficult, and it is convenient rather to define a small number of *performance categories*, i.e. descriptions of different levels of performance that may be achieved, expressed as mini-scenarios (the hypothetical alternatives or outcomes mentioned earlier). Each actual alternative is then classified into that category which best matches its performance in terms of this criterion (or possibly classified as falling between two adjacent categories). Since the categories are preference-ordered, this implies a partial ordering of the alternatives, which is usually adequate for the application of many MCDA procedures (especially when linked to extensive sensitivity studies).

In some of the MCDA methodologies described later (in Section 2.4), scores will be associated either with the rank-ordered alternatives or with the categories. This can be an extremely useful device, but can also be highly misleading if improperly used, and we shall delay discussion of scoring processes to Section 2.4.

In other cases, criteria may naturally be associated with quantitative *attributes* describing the alternatives, for example cost, streamflows or water quality measures. The ordering of the alternatives are then implied directly and require no further judgmental inputs. While this is useful, care often needs to be taken in interpreting the attribute values. There is often a temptation to apply simple mathematical scoring functions to these values which may miss the existence of threshold values (below or above which serious problems may occur), or of changing marginal returns to scale. These problems will also be discussed further within the context of different methodologies for MCDA described in Section 2.4.

2.1.3 Aggregation across criteria

This is perhaps the most crucial phase, in which the generally conflicting preference orderings corresponding to the different criteria need to be reconciled or aggregated to produce a final overall preference ordering. The process can never be exact, as it must inevitably involve imprecise and subjective judgements regarding the relative importance of each criterion. Nevertheless, with due care and sensitivity analysis, a coherent picture can be generated as to which are the most robust, equitable and defensible decisions.

An important point to recognize is that the method of aggregation is critically dependent upon the methods of evaluation of alternatives used in the previous phase. We had noted in Section 2.1.2 that a minimal requirement of an operationally meaningful criterion, is that alternatives can in principle be rank ordered from most to least preferred in terms of this criterion. If such rank ordering is the only preference information available differentiating between alternatives on each criterion, then the aggregation phase can be viewed formally as a mathematical "mapping" of a set of individual rank orders into an aggregate overall rank ordering, which is tantamount to some form of voting rule. A theoretical problem which arises at this point is that of *Arrow's Impossibility Theorem* (e.g. Kelly, 1988), which demonstrates that there exists no such voting rule (aggregating three or more rank orders) which ensures that the relationship between the individual and final rank orders satisfies a small number of plausible rationality axioms, viz:

(i) *Monotonicity*: If a particular alternative is re-evaluated according to one or more criteria, and its position in each ordering is either unchanged or improved, then its position in the aggregate ordering cannot worsen;
(ii) *Independence of irrelevant alternatives*: If elimination of one alternative from consideration does not result in a change of relative rank ordering of the remaining alternatives for any criterion, then this should also be true for the aggregate ordering;
(iii) *Individual sovereignty*: No aggregate rank ordering should be precluded by the voting rule itself;
(iv) *Non-dictatorship*: There is no criterion such that the aggregate rank ordering and the ordering for this criterion are identical irrespective of the orderings for other criteria.

In the light of the problems arising when using purely ordinal information, most MCDA methods do seek to obtain and to use stronger preference information (i.e. evaluations of alternatives according to each criterion), which then also influences the methods of aggregation to be used. This we discuss further in Section 2.4.

Aggregation inevitably involves some assessment of the importance of each criterion relative to the other criteria. This is typically expressed in terms of some form of quantitative "*weight*" to be associated with each criterion, as an indication of their relative importance. The meaning, interpretation and assessment of importance weights is an often controversial aspect of MCDA practice. Many people will express judgements of importance (e.g. that environmental issues are "much more important", or "safety is much more important than costs"). When pressed, people may even associate numerical values with these judgement, e.g. "safety is at least 5 times as important as cost". It is often tempting to use such numerical values to establish the importance weights in MCDA models. *This can be highly misleading and even dangerous*! There are at least two reasons for this assertion:

- The appropriate weights to use in a model are context-dependent. Perhaps safety is, in a general sense, much more important than cost, but it is (for example) unlikely that society would agree to strategies which would increase transport costs by a factor of 10 in order to secure a 1% reduction in expected fatalities from road accidents. In comparing alternatives, therefore, the ranges of outcomes need to be taken into consideration when establishing importance weights. The importance of cost factors in selecting a dam site must receive much less weight if all options differ by less than 10% on cost, than it would if costs of options differed by a factor of 2 or 3. It is for this reason that we have recommended "swing weighting" or the direct use of trade-offs in our discussion above.
- The appropriate weights to use in a model are dependent upon the methodology used, and in some cases on the scaling used within the model. The weights used in outranking and value measurement approaches have such different meanings that there is no reason why they should be the same.

It must be emphasized that any use of MCDA methods needs to be subject to substantial and systematic sensitivity analysis, both as regards importance weights and as regards the evaluations of alternatives according to each criterion. The critical role of importance weights, and the problems of their interpretation are amongst the reasons why we recommend that the application of MCDA be carried out under the guidance and facilitation of an expert decision analyst who is familiar with the underlying theoretical principles.

2.2 MCDA as a means of facilitating transparency and communication

In the previous section we have described the general concept of MCDA. Before moving on to more technical descriptions of the contexts in which MCDA may be applied and the underlying methodologies, it is useful for a moment to pause, and to examine briefly the question as to why use (formal) MCDA approaches, rather than to leave the problems to "gut-feel" intuition and/or to unsupported political negotiation.

As we have indicated earlier, intuition and political processes are important in reaching policy decisions. Nevertheless, we can identify two important reasons why formal MCDA should be included as an essential part of the planning process, namely those of ensuring transparency in the planning process (so that all participants can see that "justice has been done"), and of facilitating communication of values between divergent interest and stakeholder groups, and between these groups and policy decision makers. Let us look briefly at each of these two issues.

2.2.1 Facilitating transparency

The three steps of the MCDA process (identifying and structuring criteria, evaluating options in terms of these criteria, and aggregating preferences across criteria) is in fact implicit in any decision making, whether made explicit or not. The advantage of invoking formal MCDA processes is precisely that they are made explicit! The cynic might suggest that some decision makers will not want their value judgements and reasons for choice made explicit, but transparency in public sector decision making is generally accepted to be the ideal.

The value tree makes explicit what issues were taken into consideration in coming to a decision. The evaluation of alternatives according to each criterion makes explicit the manner in which alternative policy scenarios are perceived to contribute towards the associated goals. Finally, the aggregation process makes explicit the implicit value tradeoffs which have been made. Once explicit, all three phases can be subject to public debate. Are there criteria which have not been taken into consideration? Do the rank ordering of alternatives according to a particular criterion, and (even more importantly sometimes) the reported "gaps" between the alternatives on this criterion, make sense. Do the weights attributed to different criteria properly represent societal values, and how sensitive are the conclusions to these weights? These are all subjective value judgements, but the manner in which they have been incorporated into the planning process are recorded in the MCDA process, in a manner which is accessible to all role-players. In short, the use of MCDA provides an *audit trail*, documenting the manner in which conclusions were reached.

An associated issue is that of *coherency* in decision making. Choice of criteria, evaluation of alternatives in terms of the criteria, and selection of importance weights are all subjective value judgements that cannot have any objective validity. What MCDA does, however, is to impose a discipline on the planning process which ensures a degree of coherency. The same rules are used for all comparisons between alternative policy scenarios, so that the arguments used for selecting option A over option B do not conflict with those used for selecting B over C, thus helping to avoid manipulation of the agenda, or use of inconsistent tradeoffs (such as the monetary value of environmental benefits, for example) at different stages of the process. Some of the MCDA tools discussed in Section 2.4 (especially those based on value measurement theory) go further than this, by ensuring the preferences which are derived or constructed are consistent with well-defined rationality axioms such as transitivity of preferences or independence of irrelevant alternatives. There is been much debate about these axioms, as there is no doubt that unsupported decision makers do violate them, but in the view of the authors these axioms do ensure a level of coherency without which it is difficult to justify ultimate decisions.

2.2.2 Facilitating communication

A feature of public sector planning and decision making is often a breakdown in communication between different role players and stakeholders. One group cannot understand why another is so close-minded and illogical that they cannot see what the first group perceives to be the "obviously" best strategy. Although some conflicts may irrationally be based purely on dislike for another person or group, it is probably true that many more conflicts are due to different criteria or different trade-offs between them, or simply a lack of trust in decision makers. The issue of transparency discussed in the previous section can go some way towards dispelling distrust. But the MCDA process can also facilitate communication more directly.

The value trees used, especially by different stakeholder groups, give immediately a picture of what different groups deem to be important. The rank orderings of alternatives in terms of the criteria communicate a clear indication of the operational meaning of each criterion, and reasons for preferring one option to another. If stronger preference information such as the preference "gaps" between alternatives are also provided, then this will communicate further how strongly one or other group feels about choices between alternatives.

Conflicts between groups may then be seen to result from one of two sources, namely either the existence of criteria used by one group that have not been recognized by another, or substantially different relative importance weights attributed to the criteria. In the first case, the identification of the criteria used by each group will be evident from the MCDA process and is easily communicated to all parties. In the case of different importance weights, MCDA of itself cannot resolve the problem, but it will reveal the source of the problem. Reasons for different importance weightings can be discussed, and may reveal that different groups are basing their assessments on different contexts, such as different ranges of perceived outcomes. Even if no resolution to the difference in assessments can be reached, use of MCDA may still assist in identifying policy scenarios which are robust in the sense of being sufficiently good on those criteria on which there is conflict, so that the conflict has minimal impact.

It is important to note here that in the MCDA process, comparisons are not reduced to artificial financial measures such as equivalent monetary values or "willingness to pay", as is common in cost-benefit analyses. These are always potentially dangerous concepts, as they are so easily confounded by cultural differences and differing wealth levels between stakeholder groups. The MCDA process initially compares alternatives with each other in terms of each criterion, which provides a common currency or standard of comparison which is understandable to all participants. Of course, at the end of the day, the aggregation process will imply some form of trade-off between financial and non-financial costs and benefits, and it is always useful to calculate what these are as a realism check, but this is the output of the MCDA process rather than the input.

2.3 Levels of planning to which MCDA may be applied

As has been indicated earlier, MCDA processes are relevant and may usefully be applied at various stages of the planning process. Some of the tools of MCDA which we discuss in Section 2.4 may be more relevant to some stages or levels of planning than others, but the general principles discussed in Section 2.1 will apply generally.

We now identify some key planning stages and the role of MCDA in each.

2.3.1 Initial (technical) screening of alternatives

At early stages of planning processes, there are very large numbers (perhaps infinitely many) of potential options available. These may well be represented implicitly in "mathematical programming" terms by "decision variables" or "activities" which have to be selected. Such decision variables may be either continuously defined (e.g., levels of restriction on water use, amounts of land allocated to different uses), or discrete (e.g. binary choices such as whether or not to construct a dam at a specific site). A combination of feasible values for each decision variable or activity defines in principle a policy option or alternative (or what we have elsewhere termed a "*policy scenario*"). In practice, from this very large or even infinite number of potential policy scenarios, it is necessary to select out a relatively small number of options for detailed evaluation and comparison.

The process of selecting a short-list of alternative policy scenarios for detailed evaluation is itself a decision problem, although this is often not widely recognized. The selection process requires rapid technical screening of options, and needs thus to be carried out be technical staff in the backroom, seeking to interpret societal goals. This is the first stage of "multiple criteria decision making": the criteria need to reflect societal goals, but at this stage must be linked to relatively well-defined objective attributes and goals. There is no intention at this stage to identify an "optimal" solution, but the aim is rather to provide a representative set of potentially good policy directions. The policy scenarios included in this set should all be "potentially optimal", but should also be distinctly different from each other to maintain a rich variety of choice.

It is worth emphasizing here that the process will generally be iterative. After the selected policy scenarios have been evaluated by various interest or affected groups, some will need to be discarded as not providing a sufficient level of satisfaction to certain sectors of society. The technical screening may then need to be repeated, taking such dissatisfaction into account, to produce a new set of perhaps more refined policy scenarios. (See Stewart and Scott, 1995, for further discussion.)

2.3.2 Facilitation of impact studies

Once one or more policy scenarios have been identified, the next step is often to execute some form of impact assessments. Typically, these involve detailed investigations by a number of teams, aimed at establishing the "impacts" of proposed actions or policies on society at large (often split into social, environmental and economic impacts). The intention is, of course, to provide all interested and affected parties, including political decision makers, with a synoptic overview of the consequences of the proposals. Generally speaking, impacts to a large extent can only meaningfully be evaluated in a relative sense, as absolute measures of social or environmental conditions are difficult to specify unambiguously. At very least, the assessments need to be expressed relative to some well-defined baseline such as the status quo or some pre-development pristine state. A richer and consequently more meaningful set of assessments is obtainable by conducting the impact studies for a range of policy options, such as the policy scenarios selected as described in Section 2.3.1.

In some cases, impact studies may explicitly avoid providing aggregate summaries which clearly define preferences from specific perspectives (such as water quality, or social benefits). The impact assessment report will then do no more than document available information (from experts and/or community scoping). A reason for this approach may be a belief that an impact study should not include value judgements. A counter-argument, however, is that the large amount of conflicting information contained in such a report might confuse rather than enlighten. In order to provide greater levels of insight and understanding to non-expert groups or decision-makers, it may be extremely useful for relevant experts to indicate an overall relative value and/or explicit preference ordering amongst the policy scenarios under consideration. For example:

- Aquatic biologists might provide an overall evaluation of desirability for each policy scenario, taking into consideration impacts on a wide variety of species and on general water condition;
- Sociologists might provide an overall evaluation of desirability for each policy scenario, taking into consideration impacts on various sectors of the community (young and old, male and female, wealthy and poor), and on different groups (e.g. different villages).

Such overall evaluations would again be *multiple criteria decision making* problems, in the sense that each expert group would have to make decisions regarding their overall evaluations which need to balance conflicting criteria even within their own fields of expertise. The MCDA approach defined in Section 2.1, and the tools of MCDA as discussed in Section 2.4, are thus directly relevant to well-formulated and structured impact assessments. It is for this reason that software (under the name DEFINITE, or BOSDA) is being developed in The Netherlands, where MCDA concepts are routinely included as part of impact assessments (see Commissie voor de milieueffectrapportage, 1997).

As with the class of problems described in Section 2.3.1, the use of MCDA for impact assessments will also be based primarily on the use of relatively objective data ("attributes" of the alternatives), although in this case some of this data could be expressed qualitatively or verbally (e.g. "poor", "satisfactory", "good", "excellent"). Unlike the case with Section 2.3.1, use would be made here of tools of MCDA designed for discrete choices, rather than for mathematical programming structures.

2.3.3 Facilitation of stakeholder involvement

An important issue in public sector planning is that of ensuring that all significant stakeholders are enabled to make meaningful inputs. There is thus the need to assist stakeholder groups, and especially those who perhaps lack technical skills, to construct and to evaluate their own goals and preferences in the light of the policy options which are being proposed. This can be done either for a single stakeholder or interest group at a time, or for a representative group covering multiple interests. In either case, this is again a multiple criteria decision making problem in the sense that each group needs to formulate its own preferences taking into account many conflicting goals. The tools of MCDA thus once again apply.

In contrast to the two previously mentioned phases of strategic planning, the application of MCDA for facilitating group processes is not a "back-room" activity, considering the more objectively quantifiable aspects of the problem. The criteria relevant here may be much more subjectively judgmental, even emotive. For example, social groups may wish to take into consideration criteria such as a sense of security or well-being, or respect for religious beliefs or burial sites. Some of the tools of MCDA to be described in Section 2.4 are well suited, and even designed for coping with such more qualitative concerns in a coherent manner. In this context, it is usual to apply MCDA thinking processes within a group workshop setting (sometimes termed a "decision conference"), under the guidance of a facilitator and analyst who are familiar with MCDA concepts.

Recall from Section 2.1, that the primary requirements for applying MCDA thinking are (a) to be able to identify all relevant criteria, possibly structured via a value tree, and (b) to be able at least to rank order alternatives in terms of each criterion (although slightly stronger preference judgements can be useful). There is evidently no restriction in including qualitative criteria in the construction of a value tree such as that illustrated in Figure 2.1. This value tree is a slight simplification of a more complete value tree for a land use planning problem discussed by Stewart and Joubert (1998), and in the original version there were additional criteria such as "personal well-being", which was defined at the time to encompass "security of tenure, stakeholding, and capacity building of people". These are clearly highly qualitative considerations, based largely on how developments were perceived to influence quality of life in a broad sense.

Once a set of criteria have been defined, the next step is (as we have seen) to rank order the policy scenarios according to each criterion. For well-defined criteria, no matter how subjective or qualitative, this step should not be overly difficult. If there is any serious hesitation evident in trying to establish the rank ordering, this almost certainly indicates that criterion under consideration contains two or more sub-criteria in conflict with each other, and it would be necessary to develop the value tree further to identify these explicitly. For example, as indicated in the previous paragraph, a criterion such as personal well-being of the local rural population may be identified initially as an important criterion. But when trying to establish a preference ordering of the policy scenarios according to this criterion, it may be found to be difficult to judge whether one scenario is preferred to another or not, and further thought might suggest that the reason for the difficulty is that some alternatives which are good on "security of tenure" may be poor on "capacity building of people", and vice versa, creating a conflict. The initial criterion would then need to be further sub-divided into the component criteria.

It is usually useful in this context to attempt to strengthen the rank order information by getting the interest group to think also of the relative "gaps" between alternative policy scenarios. Thus, for example, three possible scenarios A, B and C may be ranked in this order, but it would be useful to know that the gap between B and C is much more important than the gap between A and B. Even quite qualitative expressions of such relative importance can help considerably in identifying the best compromise or consensus alternative. The expression of such preference gaps is often usefully facilitated by the use of the "thermometer scale" idea described in Section 2.4.

Since importance weights may be rather more difficult to specify unambiguously in this context, the role of sensitivity analysis to generate understanding in the group becomes crucial, and is easily supported by software such as V·I·S·A (from Visual Thinking International), Logical Decisions, or HiView. In practice, however, it is often found that the results are relatively insensitive to precise choice of numerical weights as long as the selection of criteria and evaluation of policy alternatives against these criteria are carefully carried out.

2.3.4 Identification of potentially "optimal" options

After completion of all impact assessments (as described in Section 2.3.2), and after receipt of representations from stakeholder and interest groups (perhaps following processes as described in Section 2.3.3), decisions have to be made at the political level, either to adopt a particular strategy or set of actions, or to refer the matter back to explore other alternatives. Although the decision is ultimately in the political arena, it may often be backed up by further analyses conducted by support staff. This phase of analysis would be aimed at identifying the potentially most broadly acceptable alternatives, and would also generate the motivation for the implied recommendation. Of course, it is possible at this stage to reach a conclusion that no alternative will be broadly acceptable, indicating the need for further creative thinking around possible courses of actions and strategies.

The tasks described in the previous paragraph represent yet again a multiple criteria decision making problem, to which MCDA tools will apply. The criteria in this case will tend to be the interests of various stakeholder groups (preferably using measures such as those obtained as per Section 2.3.3), as well as general issues identified in the impact assessments that have not been taken up by any specific stakeholder group. In this sense, the criteria and assessments of alternative policy scenarios in terms of these criteria will largely be predefined. Information regarding value trade-offs will, however, be rather imprecise, so that the task of the multi-criteria decision analysts will place emphasis on identifying what conclusions (either positive, recommending particular courses of action, or negative, recommending rejection of some courses of action) can be supported by the available information. If no particular conclusions are found to be adequately supported, then this would imply the need either for further consultation and/or impact studies to obtain more refined preference information, or for identifying other courses of action.

In Section 2.4, we will be summarizing a number of different tools for MCDA, and we will also indicate how these relate to the four phases or levels of planning described above. It will be noted there that certain MCDA tools are more appropriate to some of these phases than to others.

2.4 Tools and processes of MCDA

In the previous sections we have described the basic concepts which differentiate formal MCDA from more intuitive or unstructured approaches, as well as from other methodologies such as cost-benefit analysis. We have also indicated how MCDA concepts may be applied at different phases of the planning process, and in providing both transparency and communication to the process. We shall now briefly summarize some of the main tools of MCDA, especially as they may apply to public sector decision making such as for water resource management. The field of MCDA is quite vast, and its technicalities can get quite vast, so that this summary can give no more than a flavour of the issues involved. A more detailed review is provided in Stewart (1992), while a rich source of references to the field as a whole is given in Gal, Stewart and Hanne (1999).

Three broad schools, or modelling approaches, for MCDA can be distinguished, namely those of value measurement, goal programming or aspiration level methods, and outranking. We shall discuss each of these in turn. The first two approaches can be applied in two different contexts, namely:

- **Discrete choice**, in which a selection has to made from a finite list of explicitly defined alternatives, or policy scenarios as we have termed them above;
- **Mathematical programming**, in which policy options are identified only implicitly by means of algebraic constraints on activity variables.

The outranking approaches only apply to the context of discrete choice.

For ease of presenting the various approaches, it is useful at this stage to introduce some notation. In the context of discrete choice, we shall denote the policy scenarios or alternatives by $a,b,c,...$ Within any one phase of analysis, suppose that m criteria have been identified which we shall index by $i=1,2,...,m$. If criterion i can be associated with a quantifiable attribute of the system, we shall denote the value of this attribute for alternative a by $z_i(a)$. Note that even if the attribute is naturally expressed in categorical terms (very good, good, etc.), this is still "quantifiable" in our sense as we can associate some numerical value with each category to represent the ordering. For the purposes of this report we shall not describe the mathematical programming context in any substantial detail (as this quickly becomes quite complicated mathematically).

2.4.1 Value measurement

In this approach, we seek to construct some form of value measure, or score, $V(a)$, for each alternative a. In principle, the value measures do not possess any particular numerical properties apart from preservation of preference order, i.e. such that $V(a)>V(b)$ if and only if a is preferred to b.

Within the usual framework of MCDA, we start by extracting partial values or scores for the alternatives as evaluated in terms of each criterion. These we denote by $v_i(a)$ for $i=1,2,...,m$. Clearly V(a) must be some function of the partial values $v_1(a)$, $v_2(a)$, ..., $v_m(a)$. We shall suppose that the selection of a family of criteria satisfies the properties discussed in Section 2.1.1 (and in particular the property of preferential independence), and that the partial values are constructed so as to satisfy an *interval scale* property (i.e. such that equal increments in any specific $v_i(a)$ have the same impact or value in terms of tradeoffs with other criteria, no matter where they occur in the available range of values). It can be shown that under these assumptions, it is sufficient to construct $V(a)$ as an additive function of the $v_i(a)$, i.e.:

$$V(a) = \sum_{i=1}^{m} w_i v_i(a) \tag{2.1}$$

where the w_i is an importance weight associated with criterion i.

In applying value measurement theory, the key practical points are those of assessing the partial values and the weights.

Partial values

Partial values can be assessed by direct comparison of alternatives (only possible for the discrete choice context), or indirectly through an associated quantitative attribute z_i. Let us first examine the direct comparison approach. A useful way to assess partial values in this case is by means of the so-called "thermometer scale" provided in software such as HiView and V·I·S·A (as illustrated in Figure 2.2).

For example, in a problem such as that on which the value tree of Figure 2.1 was based, we might need to compare m=6 alternative policy scenarios, for example involving three different patterns of land use (farming, forestry and conservation) with and without the construction of a proposed large dam. For convenience, we might label the alternatives as "scenarios" A-F. Now consider a criterion such as water supply to undeveloped rural communities in the area. Since the desirability of each scenario from the point of view of this criterion may involve consideration of a number of poorly quantified issues such as convenience of access to sufficient clean water, it may not be possible to define a simple measure of performance. By the process of direct comparison on the thermometer scale, however, we can still get a meaningful evaluation for in the value function model.

We start simply by identifying the best and worst of the 6 alternatives according to this criterion of rural water supply. (This judgement is left to those considered best able to make such as assessment.) Suppose that these are identified as scenarios C and E respectively. Then C is placed at the top of the scale (denoted for convenience in Figure 2.2 by an arbitrary score of 100), and D at the bottom of the scale (denoted again for convenience at the 0 point of the scale).

A third alternative, say scenario A, is then selected for evaluation by those performing the assessment. It is placed on the scale between C and E, in such a way that the magnitudes of the relative spacings, or "gaps", between C and A, and between A and E, represent the extent to which A is better than E but worse than C. For example, the position shown for scenario A in Figure 2.2 is at about the 75% position, suggesting that the "gap" from E to A (the extent to which A is better than E) is about three times the "gap" from A to C. Put in another way, we could say that moving from E to A achieves ¾ of the gain realized by moving all the way from E to C. There is generally no need to be overly precise in these judgements, as long as the sizes of the gaps appear qualitatively correct.

Thereafter, each of the remaining alternatives are examined one at a time, and placed firstly in the correct rank position amongst the previously examined alternatives. For example, B may then be placed below A. Once the ranking is established, the precise position of the alternative is assessed, again taking into consideration the gaps between it and the two alternatives just above and below it in the rank ordering. In this process, the user may wish to re-adjust the positions of the previously examined alternatives. Figure 2.2 illustrates a final thermometer scale for all 6 policy scenarios (alternatives), evaluated according to this criterion of "rural water supply". The full rank ordering of the scenarios is C-F-A-B-D-E. The gap between C and F is perceived to be relatively small, and even A is not far behind, so that C, F and A are all judged to be relatively good in terms of this criterion. There is then a big gap between A and B, so that the remaining three alternatives are perceived to be much less satisfactory than C, F and A, although there is little choose between B and D which are still somewhat better than E. It seems that people from widely differing backgrounds can relate relatively easily to diagrams such as Figure 2.2, and do participate freely in adjusting the gaps to correspond to their own perceptions of the values of the alternatives. The thermometer scale diagram is thus not only a useful tool for assessing partial values, but also for communication between groups.

Indirect evaluation consists of two stages. We first evaluate a *value function* which associates scores with all possible values of the associated attribute z_i between a specified minimum and maximum. In theory, this should be a smooth continuous function, but in practice it is usually sufficient to use a piecewise linear function with no more than four segments. Such a function can be constructed using the thermometer scale idea described above, but applied to (say) five evenly spaced numerical values for the attribute rather than to policy alternatives directly. For example, one of the other criteria shown in Figure 2.1 was "dry season flow" in the river. This was assessed by hydrologists in terms of the percentage reduction in streamflows below current conditions. Over the alternatives under consideration, values for this attribute ranged between 0% to 20% below current levels. The value function was thus approximated by comparing the impacts of five possible levels (0%, 5%, 10%, 15% and 20%) relative to each other, on a thermometer scale. The resulting value function could then be represented as in Figure 2.3. Once the function has been assessed, the partial value score for any particular alternative is obtained simply by reading off the function value (on a graph such as that illustrated in Figure 2.3) corresponding to its attribute value $z_i(a)$.

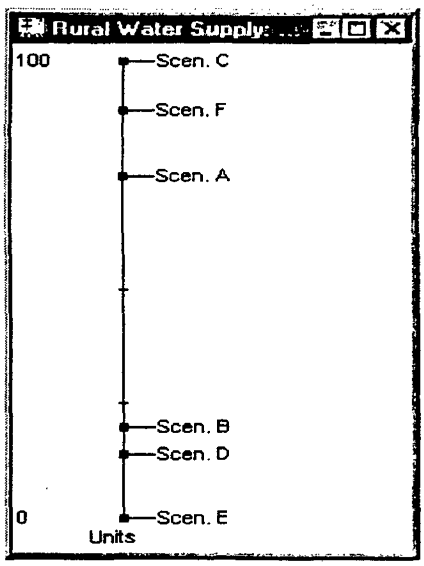

Figure 2.2. Illustration of a "thermometer" scale

It is worth noting the non-linearity in shape of the function in Figure 2.3. This is quite typical. One of the big dangers in using scoring methods such as those described here, is that users and analysts often tend to construct straight-line functions as the easy way out (often even viewing this as the "objective" or "rational" approach). Research has shown clearly that the results obtained from MCDA can be quite critically dependent upon the shape of the function, so that it is incumbent upon users of these tools to apply their minds to the relative value "gaps" between different levels of performance. Quite frequently it is found that the functions exhibit systematically increasing or decreasing slopes (as in Figure 2.3 where the slopes become increasingly negative), or have an "S" shape (or reverse "S" shape).

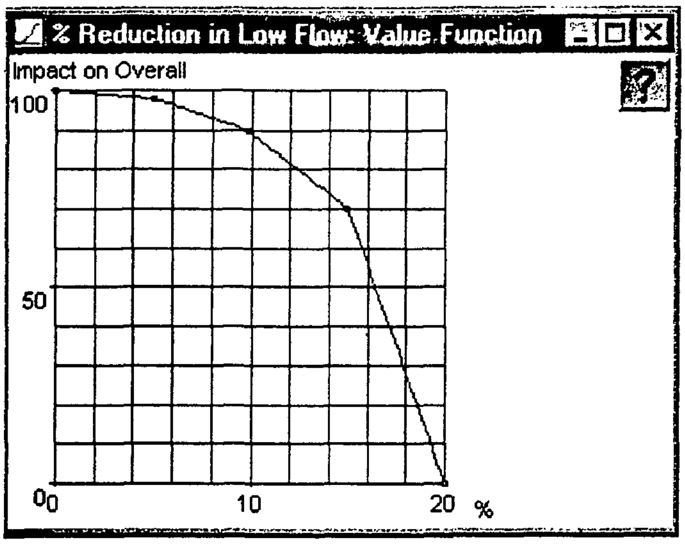

Figure 2.3. Illustration of value function.

Weights

Once the partial values have been assessed as above, the weights can also be evaluated. The algebraic implication of equation (2.1) is that the weights determine the desirable tradeoffs between the partial value scores for the different criteria, and for this reason it is important to delay assessment of weights until the people involved in the assessment have established a clear understanding of the ranges of outcomes relevant to each criterion. Various procedures have been suggested for the weight assessment, but the one of the simplest and easiest to apply is that of "swing weighting". The users are presented with a hypothetical scenario in which all criteria have the same score on the partial value function scales. Often the 0 point is suggested in the literature, but in our experience, people find it easier to start from a less unrealistically extreme position, for example one in which all partial values are 50.

The question is then posed: "If you could choose one and only one criterion to swing up to the maximum partial value score of 100, which one would it be?". This establishes the criterion having the largest weight w_i in (2.1). The question is then repeated, excluding the previously chosen criterion, to establish the second largest weight, and so on. Once we have the rank ordering of the weights in this way, we can compare each criterion with the one known to have the maximum weight, and pose the second question: "What is the value of the swing on this criterion, relative to that for the criterion with maximum weight, expressed as a percentage?". In some software, the presentation of this question is facilitated by use of bar-graphs, with the heights of the bars representing the relative importance. This gives relative values for the weights, which are usually then standardized in some convenient manner, e.g. so that the weights sum to 1.

As an example, suppose that the 3 subcriteria of the "social benefit" criterion in Figure 2.1 are compared with each other. The user might first judge that water supply (criterion 3) is more important than household income (criterion 1), which in turn is more important than number of jobs (criterion 2). This implies that $w_3 > w_1 > w_2$. Suppose that the relative importances of the swings for criteria 1 and 2 relative to criterion 3 are judged to be 70% and 50% respectively. This implies that $w_1/w_3 = 0.7$, and $w_2/w_3 = 0.5$. Typically this process would be repeated for the subcriteria of "economic" and "environmental benefits respectively", before making comparisons between the most important subcriteria for each of the highest level criteria. For example, if "forestry output" was judged the most important economic benefit, and "dry season flow" the most important environmental benefit, then we would also require the users or decision makers to compare the swings of water supply, forestry output and dry season flow with each other. Some procedures in the literature encourage direct comparison between higher level criteria (e.g. economic versus environmental benefits). This is a dangerous practice, as the operational meaning of a multi-dimensional "swing" is difficult to appreciate intuitively. See further comments on weights in Section 2.1.3.

The value function methodology as described above for the discrete choice problem is well-suited to the phases of the planning process described in Sections 2.3.2 and 2.3.3. Particularly at the point of involving stakeholders in subjective assessments for the less quantifiable criteria, the use of the thermometer scales and swing weighting (linked to extensive sensitivity analysis) has proved to be an extremely valuable tool.

Value measurement concepts can also be applied in the mathematical programming context, where it is of particular relevance at the stage of initial (technical) screening of alternatives. The implementation is technically quite complex, beyond the scope of this report, and is probably best left to technical experts (but see Stewart, 1999, for some discussion). It is interesting to note, however, that applications of value measurement concepts in multiple objective mathematical programming problems occur in two quite distinct ways:

- A value function may be set up as described above (necessarily based on quantitative attributes and partial value functions as in Figure 2.3). This can then be maximized subject to the stated constraints, using (integer) linear programming when the constraints are linear and the value function is approximated in piecewise linear form.
- Mathematical programming techniques can be used to search for ranges of potentially optimal solutions, i.e. solutions which may conceivably be optimal for some possible value function within a wide family. The search can be made more efficient by use of so-called "interactive" methods, in which the user provides some partial preference information, typically in the form of ranking a small number of feasible solutions. (It is the use of such interactive methods which is the primary thrust of the paper by Stewart, 1999.)

2.4.2 Goals and aspirations

This approach is used primarily when the criteria are associated with quantifiable attributes $z_i(a)$, and is thus possibly most appropriate at the technical analysis phase (before more qualitative, intangible and subjective criteria are taken into account). The principle is quite simple. Instead of evaluating tradeoffs and weights (as in Section 2.4.1), the user simply specifies some *desirable goals* or *aspirations*, one for each criterion. These aspirations define in a sense a *prima facie* assessment by the user of what would constitute a realistically desirable outcome.

Let g_i be goal or aspiration level specified for criterion i. The interpretation of g_i will depend on the manner in which the corresponding attribute is defined:

- *Maximizing sense*: If the attribute is defined such that larger values of $z_i(a)$ are preferred to smaller values all other things being equal (typically some form of "benefit" measure), then the implied aim is to achieve $z_i(a) \geq g_i$. Once this value is achieved, further gains in $z_i(a)$ are of relatively much lesser importance.
- *Minimizing sense*: If the attribute is defined such that smaller values of $z_i(a)$ are preferred to larger values all other things being equal (typically some form of "cost" measure), then the implied aim is to achieve $z_i(a) \leq g_i$. Once this value is achieved, further reductions in $z_i(a)$ are of relatively much lesser importance.

Sometimes planners like to target some form of intermediate desirable value, possibly something like a water temperature which should not be too hot or too cold. In this case, values of $z_i(a)$ in the vicinity of the target value g_i are desirable, with greater deviations on either side to be avoided. Since the reasons for avoiding deviations in each direction will generally be different, it is usually convenient to define two separate criteria ("not too hot" and "not too cold"), each using the same attribute, but with different aspiration levels. For example, if the desired temperature range is 15°C-18°C, then the goal for the "not too cold" criterion will be *temperature≥15°C*, while that for the "not too hot" criterion will be *temperature≤18°C*. Thus for the purposes of further explanation, we shall assume that all attributes will be defined in one of the two senses defined by the above bulleted items.

The original development of this *goal programming* approach took place in the context of linear programming (Charnes and Cooper, 1961). Many standard management science texts still equate goal programming with these original linear programming extensions, a view which Ignizio (1983) describes as a "common misconception". For this report we adopt the broader view of *generalized goal programming* as described by Wierzbicki (1999), i.e. including non-linear and discrete problems, and the so-called *reference point* approaches. (Generalized) goal programming is then based firstly on defining deviational variables $\delta_i(a)$ corresponding to the performance of each alternative in terms of each criterion, measuring the extent to which the goal is not met by alternative a, that is:

- $\delta_i(a) = \max\{0, g_i - z_i(a)\}$ for attributes defined in a maximizing sense; and
- $\delta_i(a) = \max\{0, z_i(a) - g_i\}$ for attributes defined in a minimizing sense.

Algebraically (for purposes of inclusion in mathematical programming code), the deviational variables are often defined implicitly via constraints of the form:

- $z_i(a) + \delta_i(a) \geq g_i$ for attributes defined in a maximizing sense; and
- $z_i(a) - \delta_i(a) \leq g_i$ for attributes defined in a minimizing sense,

linked to some process which minimizes all deviations as far as is possible.

The key question at this stage relates to what is meant by minimizing all deviations. Without going into any detailed review at this stage, it is this writer's view that the most robust approach is the so-called Tchebycheff norm (e.g. Steuer, 1986, Chapters 14 and 15), also incorporated into the "scalarizing function" concept introduced by Wierzbicki (1980, 1999). In essence, we identify the alternative a which minimizes a function of the form:

$$\max_{i=1}^{m} \left[w_i\delta_i(a)\right] + \varepsilon\sum_{i=1}^{m} w_i\delta_i(a)$$

where the ε is a suitably small positive number (typically something like 0.01), and the w_i are weights reflecting the relative importance of deviations on each goal. It is important to emphasize that these weights are related to tradeoffs between attributes in the vicinity of the aspiration levels, and are dependent upon the specific scale of measurement used. The best way to think of this is to evaluate tradeoffs directly. If a gain of x_r in the value of the attribute corresponding to criterion r would just compensate for a loss of x_s in the value of the attribute corresponding to criterion s, then $w_r x_r \approx w_s x_s$ so that $w_r/w_s \approx x_s/x_r$. For example, suppose we looked at a water quality attribute such as the concentration of some contaminant expressed in *ppm*, and a streamflow attribute such as minimum flow in the dry season expressed in m^3/sec. If it was agreed that a decrease in concentration of 10*ppm* (this is of course a minimizing attribute, so that the decrease is a gain) would compensate for a reduction in minimum flow of $0.1m^3/sec$, then $w_{contamination}/w_{streamflow} \approx 0.1/10 = 0.01$. This does not mean that the pollution issues have low importance, but reflects the particular units of measurement. If streamflow were measured in *litres/sec*, then the weight ratio would be 1000 times larger.

The above process can be applied in either the discrete choice or the mathematical programming contexts. For discrete choice, the calculations for each alternative are easily set up in a spreadsheet. For example, suppose that we are evaluating 6 alternative policy scenarios, and that 4 critical criteria have been identified, associated with the four quantitative attributes: investment cost (Rm), water quality (ppm of contaminant), minimum flow levels in the river (m^3/sec), and recreational access (thousands of person days per annum). Suppose that the values of these criteria for the six alternatives are as follows:

Alternative	Costs (Rm)	Quality (ppm)	Minimum Flow (m^3/s)	Recreational Access (pers-days)
Scen A	93	455	1.8	160
Scen B	127	395	1.9	190
Scen C	88	448	1.5	185
Scen D	155	200	2.5	210
Scen E	182	158	3.1	255
Scen F	104	305	1.7	220

Note that the first two attributes require minimization, and the latter two maximization. Suppose that goals are specified as follows: R120m for cost, 280ppm for quality, 2.5 m^3/sec for minimum flow, and 225 person days for recreational access. The unweighted deviations ($\delta_i(a)$) can be computed as follows:

Alternative	Costs	Quality	Minimum Flow	Recreational Access
Scen A	0	175	0.7	65
Scen B	7	115	0.6	35
Scen C	0	168	1	40
Scen D	35	0	0	15
Scen E	62	0	0	0
Scen F	0	25	0.8	5

We illustrated the computation of relative weights above. Suppose that by this process, the weights relative to the minimum flow criterion are assessed as follows: w_1=0.025 (costs), w_2= 0.01 (quality), w_3=1 (for minimum flow by definition) and w_4=0.01. (These correspond to equivalences between changes of R4m in cost, of 10ppm in quality, of 0.1 m^3/sec in minimum flow, and of 10 person days in recreational access.) Using these weights and ε=0.01, we obtain the following values of the function given by expression (2), for each of the alternatives:

Scen A	1.781
Scen B	1.173
Scen C	1.711
Scen D	0.885
Scen E	1.566
Scen F	0.811

Scenario F is then indicated as the best compromise, followed closely by Scenario D. The remainder are shown to be considerably worse, in the sense of having large deviations for one or more criteria.

For a small number of alternatives, as in the above example, the goal programming or reference point approach does not generate too much insight. The methods come much more into their own, however, when there are a large number of alternatives that have to be screened, and especially when the problem has a mathematical programming structure. In the linear programming case, the trick is to minimize a new variable D, subject to the constraints $D \geq w_i \delta_i(a)$, to the constraints described above for implicitly defining the deviational variables, and to the natural constraints of the problem. The proper setting up of the problem for solution would generally require the assistance of a specialist skilled in (multiobjective) linear programming and we shall not attempt to provide all the details here.

As this goal programming approach requires that all criteria be representable in terms of quantified attributes, it will generally not be suitable for situations in which important criteria are of a strongly subjective nature. Goal programming is thus probably best suited to the technical prior screening of alternatives (see Section 2.3.1), with some potential for application at the stage of generating potentially optimal solutions (Section 2.3.4).

2.4.3 Outranking

A third school of MCDA which is popular in Europe, especially in countries with strong links to France, is that of outranking. As the basis of the approach lies in pairwise comparison of alternatives, it is in practice restricted to discrete choice problems.

In essence, the outranking approach attempts to characterize the evidence for and against assertions such as "alternative a is at least as good as alternative b", rather than to establish any form of "optimal" selection *per se*. Initially, alternatives are compared in terms of each criterion separately, much as in value function approaches. The tendency is to make use of attribute measures (which we have previously termed $z_i(a)$) to facilitate this comparison, although these attributes may be expressed on some form of nominal scale. The attribute values tend to be used in a relatively "fuzzy" sense, however, so that (for example) alternative a will only be inferred as definitely preferred to b if the difference $z_i(a)-z_i(b)$ exceeds some threshold level.

In determining whether alternative a can be said to be "at least as good as" alternative b, taking all criteria into account, two issues are taken into consideration:

- Which criteria are *concordant* with the assertion? A measure of *concordance* is typically defined as the sum of weights associated with those criteria for which a is distinctly better than b, when the weights are standardized to sum to one. It must be emphasized that the weights have a very different meaning to the trade-off interpretation described for the other two schools of MCDA. For outranking, the weights may best be seen as a "voting power" allocated to each criterion, representing in an intuitive sense the power to influence outcomes that should be vested in each criterion.
- Which criteria are strongly *discordant* with the assertion, to the extent that they could "*veto*" any consensus? A measure of *discordance* for attributes defined in a maximizing sense is typically defined by the magnitude of $z_i(b)-z_i(a)$ (since by assumption $z_i(a)\leq z_i(b)$ for discordant maximizing attributes), relative to some pre-defined norm. The overall measure of discordance is then the maximum of the individual measures for each discordant criterion.

In order to illustrate the concordance and discordance principles, consider the hypothetical comparison of two locations for a dam, compared in terms of four criteria: cost (in Rm), number of people displaced, area of sensitive ecosystems destroyed (in km^2), and impact on aquatic life (measured on a 0-10 nominal scale, where 0 implies no impact which is ecologically most desirable). Suppose assessments for the for the two dams have been made as follows:

	Cost (Rm)	Number Displaced	Area Lost (sq.km.)	Ecological Impact
Location A	18	200	30	7
Location B	25	450	5	4
Criterion Weight	0.35	0.25	0.25	0.15
Norm for assessing discordance	10	350	30	9

Location A is better than location B on cost and number displaced, and thus the concordance index for A versus B is 0.35+0.25=0.6. Correspondingly, the concordance for B versus A is 0.4.

The discordant criteria for A compared to B are area lost and ecological impact, with relative magnitudes 25/30=0.83 and 3/9=0.33 respectively, so that the overall measure of discordance is 0.83. Similarly, the measure of discordance for B compared to A is the maximum of 0.7 and 0.71, i.e. 0.71.

The methods based on outranking principles, particularly the various "ELECTRE" methods (see, for example, Vincke, 1999), compare all pairs of available alternatives in the above manner. Any one alternative a is said to *outrank* b if the concordance is sufficiently high and the discordance sufficiently low. In some implementations, the outranking is viewed as "crisp", i.e. an alternative either does or does not outrank another, the decision being based on whether the concordance exceeds a pre-defined minimum level and the discordance does not exceed a pre-defined maximum level. In other implementations a "fuzzy" degree of concordance is constructed from the concordance and discordance measures. In either sense, the result is a measure of the extent to which the evidence favours one alternative over another. This could lead to elimination of some alternatives and/or the construction of a short-list of alternatives for deeper evaluation.

The techniques by which outranking methods establish partial or tentative rank orders of the alternatives is technically very complicated, and beyond the scope of this discussion. The reader is referred to Vincke (1999) for a somewhat more detailed discussion and many references to the techniques.

Outranking methods are relevant to situations in which (a) there are a discrete number of alternatives under consideration, and (b) preference information such as detailed value trade-offs are not easily available (typically because the analysis is being carried out by expert groups on behalf of political decision makers who have been unwilling or unable to provide the sort of information required by the other two schools of MCDA). It appears, therefore, that outranking methods may be best suited in the context described in Section 2.3.4.

2.5 Considerations of uncertainty and risk in MCDA

In the above explanation of the tools of MCDA, it has been assumed implicitly that alternatives can be compared relative to each other in terms of each criterion with a reasonable level of certainty or confidence. This may not always be true, either because of a lack of knowledge (uncertainty) concerning the systems being compared, or because the outcomes may be dependent upon future uncertain events such as economic or climatic conditions (risk).

Where the extent of the uncertainties or risks are relatively small, they can be accounted for by performing sensitivity analysis on the effects of the relevant inputs on the results of the decision analysis (and most supporting software allows this to be done with some ease).

When the uncertainties or risks are a substantial feature of the decision problem, however, something else needs to be done. The concepts of value measurement have been extended to incorporate multiattribute expected utility theory, which in principle allows uncertainties to be included directly in the analysis. In many cases, however, it is difficult to check or to validate the numerous additional assumptions which have to be made, the models become much more complex to assess, and the required probability distributions may not easily be available. In most cases, it thus seems that some form of scenario planning is necessary (cf. van der Heijden, 1996). There are two possible ways in which this may be done:

(1) Carry out the entire analysis for each scenario representing uncertain or future conditions: Those alternatives which are revealed to be good compromises under all scenarios would presumably be the preferred option.

(2) Represent performance in terms of each initial criterion under the assumptions of each scenario as a criterion in its own right: This does multiply the number of criteria being considered in the analysis, but may generate useful insights (cf. Stewart, 1997).

Chapter 3. Processes and Tools

This chapter states briefly the SBPP/MCDA[2] process or framework as developed through this and previous projects, and the *tools* and *techniques*, including software, which are associated with each stage of the process. Chapter 2 and Chapter 3 overlap: Chapter 3 can be seen as the 'practical guide to stages' for ease of reference in the following chapters, while Chapter 2 gives general background, information about other approaches, and theoretical detail about specific stages. It is essential that Chapter 3 is assimilated before reading the remaining chapters, as reference is made throughout to various stages, processes and tools.

It is important to understand, firstly, that MCDA refers both to a generic process (framework or protocol) for decision-making, and to the specific MCDA tools or techniques which could be used at various stages within such a process, and secondly, that it is intended to be flexible. The process and tools below are written for a generic 'water resource management' situation and details will differ for different types of applications. The process and tools described below could be used in the classification of water resources into management classes, or they could be used for developing and choosing between catchment management strategies. In either case, the exact terminology, level of detail, etc. might differ. In other types of decision problems (such as classification and prioritisation), it is mainly the development of criteria and scoring systems (indices) which will be used. In whatever context, the process and tools are intended to be flexible and adaptable to the particular situation.

In our previous WRC projects it was found that in water resource management situations there were often no pre-existing alternatives, and that an important part of the problem structuring stage was that of defining alternatives. For this reason the SBPP process was developed (Appendix 3.1 outlines the original form of SBPP), to be integrated with the typical MCDA process and allow for scenario development (Figure 3.1). The combined process is termed SBPP/MCDA for the remainder of this document where scenario development is included, or MCDA where this stage is excluded. The Sand River (Chapter 7) and Maclear (Chapter 8) cases illustrate the SBPP/MCDA process and tools, and the reader is referred to these chapters for examples. The other case studies used various MCDA tools.

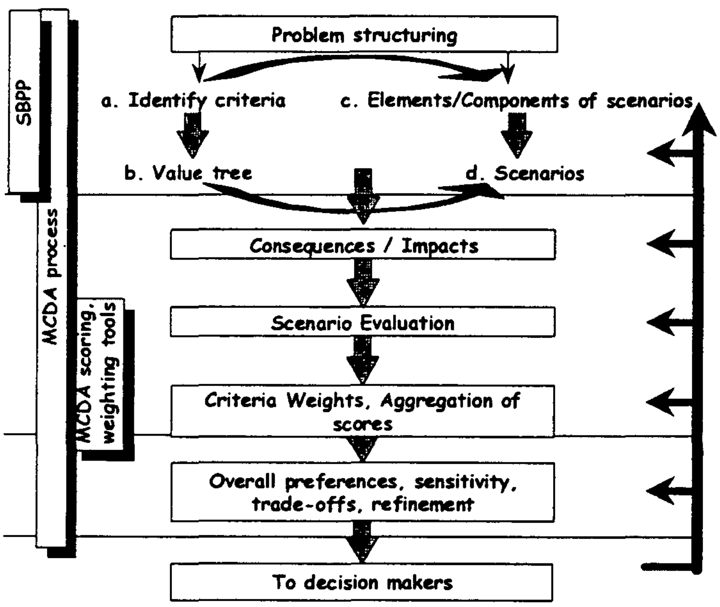

Figure 3.1. Outline of the SBPP/MCDA process. The process is likely to be iterative and non-linear.

[2] Scenario Based Policy Planning. Multi-Criteria Decision Analysis (or Aid).

3.1 The combined SBPP/MCDA Process

The generic SBPP/MCDA process is outlined in Figure 3.1 and Table 3.1 summarises each stage. Within each of these stages, various techniques have been used, and those which were found to be generally accessible and acceptable are included in the relevant SBPP/MCDA process stage. In specific situations other techniques could be used, but these would often be undertaken by the analyst, and in effect be 'irrelevant' to the group(s) involved in the problem.

It is envisaged that all stages will occur with a *'facilitator/analyst'* guiding the group(s) through the process in a workshop or series of workshops. Someone already trained in facilitation would need perhaps a two or three week long course covering the main details of the process and tools in order to be able to fulfil the role of analyst within a particular problem context. A longer course would be necessary if the analyst would need to be comfortable with some of the variations of the tools mentioned below. The number of workshops required to complete the process would be completely context dependent. One workshop might be sufficient in a reasonably contained or well-defined problem, whereas, in many cases around four workshops would be needed (excluding time needed for data-gathering, modelling etc.).

The VISA software (Visual Thinking International, 1995) and the software described in Chapter 10 are designed to facilitate this process, and are quite easy to use and extremely useful as visual aids within workshops. However, the scoring, weighting and aggregating can all be done in an Excel spreadsheet set up for the purpose. There are a multitude of other MCDA support software packages, each having their own approach to techniques, and their own strengths and weaknesses.

Table 3.1. SBPP/MCDA framework, with some details on methods at each stage. Percentages refer to an approximate amount of the total time taken up by each stage, based on local experience.

1. Problem structuring stage: identify scenarios and criteria		**± 50 %**
This is a two pronged stage, most probably occurring in parallel, the objectives of which are to identify scenarios and criteria for their evaluation.		
1.1 Define scenario elements and scenarios	**1.2 Define objectives, goals, criteria**	
• Explore and *define the problem* (What needs to be decided? Why?).	• Brainstorming, nominal group technique or other methods: **criteria** are chosen for evaluation of scenarios.	*Facilitated group.*
• Groups suggest *'worst' and 'best'* options, *'visions'*, *strategies*, *'critical uncertainties'* and *'trends'*	• A value tree is formed.	*Facilitated group*
• The essential components / building blocks / elements of the scenarios are identified and operationalised e.g. land- and water-use may be components of a 'land-care and water conservation catchment plan'.		*Analyst/ Facilitated Group*
• A set of scenarios is formed which includes options which might satisfy the represented stakeholders		*Facilitated group*
2. Determine relevant consequences and evaluate scenarios		**± 15%**
Is specialist judgement sufficient or are more data, further studies, modelling required.		*Facilitated group.*
The relevant **consequences** of the scenarios are determined (modelling, studies, data collection) before the next stage. [*Time estimates do not include this stage*]		*Studies/ Models*
The scenarios are **evaluated** by the group(s) using an appropriate value measurement approach (beans or stones, thermometer scales, value functions, verbal scales, ordinal scales).		*Facilitated group*
3. Obtain overall aggregate preferences		**± 15%**
The criteria are weighted by the group(s) using swing **weights**. Relevant comparisons are prepared in advance by the analyst, to ensure that the maximum information is obtained from the minimum number of questions.		*Facilitated group*
The scores are **aggregated** in a way acceptable to the group by discussion (weighted sum, max-min, if-then-else).		
4. Sensitivity analyses and feedback		**± 10%**
The analyst performs appropriate *sensitivity analyses* on weights and scores. The analyst may at this point analyse a 'background set' generated by the scenario elements, and using random weights or other techniques determine whether other scenarios need to be presented to the group(s).		*Analyst*
The analyst reports relevant information to the group.		*Facilitated group*
5. Discussion to consensus or further iterations		**± 10 %**

3.2 Problem structuring

It is important that the group(s) gain a reasonably common understanding of the problem being addressed. In general the problem structuring stages will occur in a workshop session(s) where techniques such as brainstorming and cognitive maps (Figure 3.2) would initially be used in a 'free-session'. During the initial session, the facilitator/analyst will ask key questions aimed at identifying (in depth exploration occurs at a later stage) the dimensions of the problem, including issues of concern, objectives, strategies, visions, constraints, relevant stakeholders etc. The format of this session would depend on, and be structured to conform to the decision context. It is not expected that everything will be dealt with in this first session, but that the key elements of the problem are defined, which will then inform the structuring of the following sessions. Obviously, in some cases, these aspects are already clearly defined, and a 'free' session is unnecessary.

'Post-its' can be used by the group(s) to respond to guiding questions, and the contributions grouped into appropriate categories, and/or linked to form cognitive maps. Software exists for generating ideas (e.g. GroupSystems, Ventana Corp. 1994) and for developing cognitive maps (e.g. Decision Explorer, Banxia Software 1996) but either of these can as effectively done with 'post-its', drawn by hand or any graphics package. As the name suggests cognitive maps help to ensure that the group(s) has a similar comprehension of the dimensions of the problem, and that necessary links are made between the different dimensions. This allows a 'systems' view of the problem to evolve which helps in later stages and in forming a consensus 'vision' (and can be used to develop systems models using packages such as STELLA, High Performance Systems 1996).

The facilitator/analyst should be involved as early as possible in the project, in order to avoid repetition of internal problem structuring exercises that groups may conduct as part of a broader project. It might be appropriate that the facilitator/analyst is simply an observer in these processes and records relevant information for structuring the first SBPP/MCDA workshop.

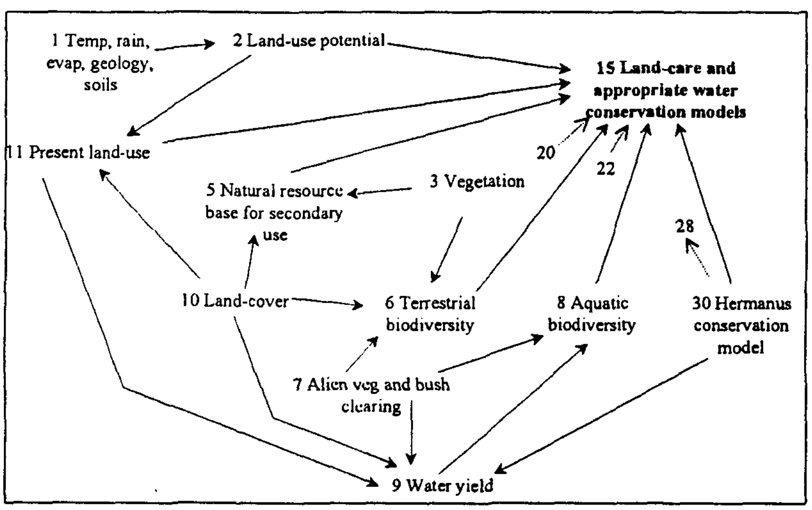

Figure 3.2. An example of a cognitive map used in the early problem structuring stage of the Sand River catchment planning project (mainly by the analyst).

3.2.1 Scenario development

There are two stages to scenario development, the first to identify common elements / components / or building blocks of scenarios, the second to combine these into a manageable (7 ± 2) list of scenarios. In some cases, it may be possible to immediately define scenarios, however, having common elements helps ensure that there is internal coherence and consistency of the problem.

In many situations the decision context will pre-determine the scenarios or alternatives (on a broad level). For example, in the process of classifying water resources into management classes, the scenarios could be the different management classes A to D (giving 4 scenarios) (see Sections 4.1.1 and 4.2), and this set could be enriched by forming 'intermediate' scenarios. Each of these management class scenarios would have to specify the wider implications and consequences (the attributes in our terminology), including economic, social, and ecological attributes. These attributes would then be the scenario elements described in the next section and/or the criteria by which the scenarios are evaluated.

In other situations it may initially be unclear what needs to be compared and evaluated: this is the reason for the elaboration of the scenario development stages. This was in fact the case for the Sand River catchment planning example (see Chapter 7), and it took some time to clarify the situation.

Identifying scenario elements

The initial brainstorming and cognitive maps session can be structured so as to obtain some relevant material, but at least one and possibly all of the following approaches would be needed to draw out an appropriate list of elements:

- Ask the group(s) directly to consider what these elements might be ('What are the essential components of a catchment plan?', 'What are the essential elements of a statement of Ecological Flow Requirements?').
- Ask the group(s) to identify realistic 'best' and 'worst' (and perhaps 'middle') options from their point of view or from a number of points of view (depending on the make-up of the group).
- Ask the group(s) to identify, without detail, possible strategies for achieving key objectives.
- Ask the group(s) to formulate 'visions' without detail e.g. 'What would you (realistically) like the catchment to look like in ten year's time?'
- Ask the group(s) to identify critical uncertainties and trends. These help to highlight additional scenario elements or 'external' scenarios (e.g. do we need to model the effects of different population growth scenarios, do we need to include drought cycles, do we need to include different AIDS infection rates?).

Which of these were used would depend on the context, and on the make-up of the group(s) concerned.

Forming scenarios

Common scenario elements would be identified from the previous stage, and combined into a shortlist of scenarios acceptable to the group(s) (i.e. the scenarios must be wide ranging enough). For example, scenarios might be formed by:

- different hectares and geographical locations of different land-uses (e.g. Sand River and Maclear examples Chapter 7 and Chapter 8); or
- different water abstraction rates at different points along a river; or
- different dam release strategies (e.g. IFR workshop settings, see appropriate literature); or
- different domestic delivery and tariffing arrangements; or
- all of the above aspects might be combined into different scenarios (e.g. the Sabie example: Stewart *et al.*, 1993, Stewart and Scott, 1995), etc.

The group(s) needs to checks that the choosing of one or other of the scenarios is relevant e.g. Are these the decisions we need to make, are these the sorts of scenarios that will solve the problems?

3.2.2 Identification of objectives and criteria and formation of the value tree

The initial brainstorming and cognitive map session will already have identified issues of concern, objectives, etc. This aim of this session would be to define (more or less precisely) the criteria with which the group(s) will evaluate the alternatives of scenarios. Section 2.1.1 describes some approaches for identifying criteria as well as the theoretical requirements of the criteria.

The criteria are organised into a value tree which groups them into criteria groups or into higher level objectives to which they contribute (Figure 3.3). The structure of the value tree is important both because it is a cognitive aid, and because it defines the way in which the criteria scores are subsequently summed to obtain overall preferences.

At this stage within a workshop, software such as VISA is very useful: the value tree is simply displayed, criteria can easily be added, deleted and moved around with full participation of the group(s). The software described in Chapter 10 also includes value tree formation as an integral part of the process, and can combine the value trees of different individuals or groups into one tree.

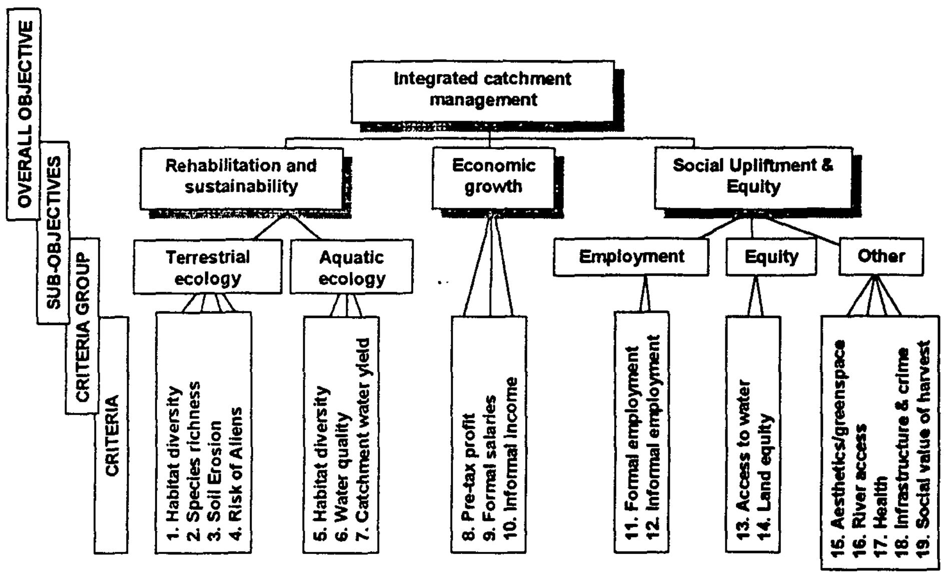

Figure 3.3. An example of a value tree.

3.3 Evaluation: Scoring and weighting

3.3.1 Determine relevant consequences of the scenarios

The group needs to decide what information is needed in order to be able to evaluate the scenarios on the basis of the criteria identified. An initial rough evaluation of the scenarios can help to clarify if available data and specialist judgement is sufficient or if further studies, modelling, data gathering are required. The emphasis is on 'sufficient' information in order to indicate relative preferences for scenarios. In many cases, a little data gathering is all that is required. Any further studies need to be completed before the next stage could be completed, although scoring could continue for other criteria.

3.3.2 Scoring and weighting

Using the 'value measurement' approach, the scenarios are given scores and the criteria are given weights so that the scores can be aggregated up to any level of the value tree. Thus, indications of preferences from the point of view of different objectives, groups and overall can be given, using:

$$V(a)=\sum_{i=1}^{n} w_i v_i(a) \quad \text{or} \quad V(a)=\sum_{i=1}^{n} w_i v_i(z_i(a)) \tag{3.1}$$

where the former is used when scores are given directly and the latter when value functions are used (see below). $V(a)$ is the aggregate value of scenario a, w_i is the weight of criterion i, $v_i(a)$ is the value of scenario a for criterion i, or v_i is the value function for criterion i, and $z_i(a)$ is the attribute level (e.g. Rands) of criterion i for scenario a. Section 2.1.3 mentions the implications of aggregation of different types of information, Section 2.4.1 discusses 'value measurement', scoring (partial values) and weighting. Section 2.4 also discusses techniques such as goal programming (all goals quantitative) and outranking (only partial rank orders obtainable in the final stage).

The specific 'value measurement' MCDA approach used in this stage is called SMART (Simple Multi-Attribute Rating Technique, e.g. Goodwin and Wright, 1998) which incorporates the use of 'thermometer scales' and 'swing weights' for weighted summation as in (3.1). Other aggregation rules might be appropriate, and these need to be assessed by the group and facilitator /analyst e.g. max-min, if-then-else types rules, or combinations of these with the above.

Evaluation of scenarios - scoring

During this workshop session, all scenarios are given a score on a 0 to 100 'thermometer scale' on each criterion. The scores need to be given in such a way that the scale is an 'interval' scale[3], so that the gaps in score between the scenarios show the relative differences between, or the relative preferences for scenarios for that criterion. Sections 2.1.2 and 2.4.1 discuss the comparison of alternatives, value measurement and illustrate thermometer scales and value functions (see below). Scores may be given directly or indirectly depending on the information available, the nature of the criterion, and the nature of the individual(s) or group(s).

If the criterion is by nature a qualitative or intangible issue (e.g. quality of life, habitat integrity, freedom of choice, aesthetics, social disruption) or if there is insufficient quantitative information available (e.g. species richness, erosion levels), the scores are given directly by the relevant individual or specialist. This *direct scoring* may be done in a number of different ways, in each case the best scenario is first identified, and given a score of a 100, and the worst a score of 0. Where participants are less numerate beans or stones may be distributed between different scenarios in a matrix drawn on paper or on the ground, otherwise printed thermometer scales could be used, or an overhead, or software such as VISA or that described in Chapter 10 (Figure 3.4). In cases where people feel 'nervous' about giving precise scores, a range (e.g. Scenario 1 scores between 30 and 40) could be indicated for inclusion in later analysis. Some software (e.g. WINPRE, 1995) allows one to give imprecise scores, but has not been used here for other technical reasons. In cases where people feel more comfortable with verbal scores (very good, good, bad etc.) these can be used, but will also be translated to a 0-100 scale, and a level of imprecision in these scores could be included. Sensitivity analyses can be designed to test the robustness of a preferred option to changes in scores by say 10%. One cannot (and should not) be totally prescriptive about which of these methods of scoring to use, as the facilitator/analyst will have to 'feel' his or her way with the group(s). In any case, the results should not be grossly affected by the method as long as the concept of an interval scale is maintained. A brief explanation of the reasoning should be associated with each score.

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[3] An interval scale is simply a cardinal scale without an absolute zero.

Indirect scoring is used where quantitative information is available (e.g. income, number employed, average low flow, hectares) and a *value function* can translate the quantitative data from its natural scale (Rands, numbers, m^3) to a value on a 0-100 scale (see Section 2.4.1 for details and precautions) (Figure 3.4). Software such as VISA and that described in Chapter 10 allow one to specify the (linear or non-linear) relationship between the natural scale and the criterion value, and these can also be specified within an Excel spreadsheet. In some cases, scores (direct or indirect) could be related to the distance from a goal or an aspiration level (see Section 2.4.2).

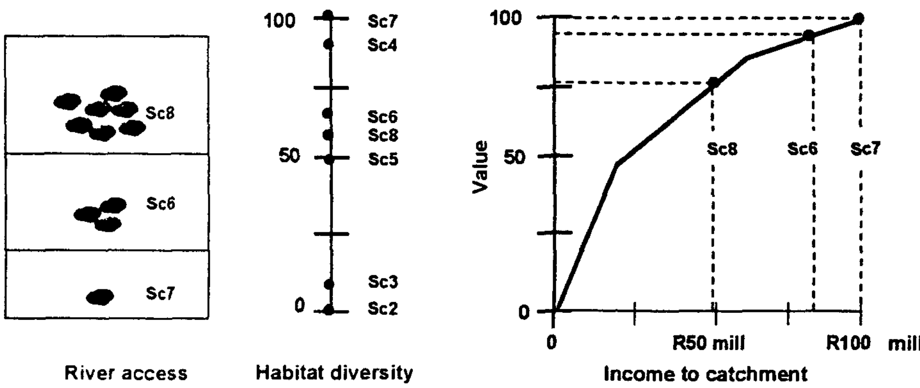

Figure 3.4. Direct scoring using stones and a thermometer scale. Indirect scoring using a value function.

Weighting of criteria and aggregation of scores

In order to complete the aggregation, weights need to be given to the criteria, and the swing weighting approach is generally used. Section 2.4.1 describes a questioning procedure for eliciting weights, and the process of standardisation. It is important that the facilitator/analyst effectively conveys the message that: the weights give the trade-off between one criterion and another, and that this trade-off is based on the range from worst to best encompassed in the 0 to 100 scale. The weights therefore in effect stretch or shrinks the scales. It is important to take note of the comments regarding importance weights in Sections 2.1.3 and 2.4.1, in particular their dependence on the overall MCDA method used.

It is often at this stage that people say that 'there is not enough information to give weights', or that 'this is too subjective' or 'too complicated'. However, any aggregation (in any explicit or implicit system) implies weights, and not giving weights does not mean that the contribution of each attribute has been equitable. It is true, however, that the elicitation of weights is subject to biases and inaccuracies, and although the sources of these are known, practical guidance to their avoidance is limited (e.g. Pöyhönen, 1998). In any case, if the group(s) is uncomfortable with giving a precise weight, a range could be given, and these ranges could be included in sensitivity analyses. In situations where different groups give different weights (their trade-offs are different), the weight sets from the different groups can be included in analyses, and differences in preferences examined. In some cases conjoint scaling may be an appropriate tool for assessing relative weights (see Stewart *et al.*, 1997).

3.4 Analysis of results: trade-offs, monetary values, value paths etc.

The scores and weights, and resulting preferences can be further examined in various ways depending on the decision context (see Chapter 7 and Chapter 8 for examples). The scenarios can be examined in terms of the ***costs and benefits*** of implementation by re-arranging the criteria into these two categories. Although one of the advantages of using MCDA is that it does not require that all values be converted into monetary terms, these monetary values may nevertheless be of interest in certain contexts. The

monetary value of non-monetary criteria can be determined by using the trade-off information contained in the scores and weights (see below). These analyses can be presented to the group(s), to help to provide a 'reality check' in assessing the validity or consistency of weights and scores. Trade-offs and monetary values are easily determined in a spreadsheet, although VISA and the software described in Chapter 10 do not presently allow the direct calculation of these values.

Trade-offs between a pair of criteria, v_1 and v_2, are determined in the following way, where w_1 and w_2 are the respective weights (see Section 7.3.2 for an example). By definition a one 'value point' change on v_1 is 'worth' a w_1/w_2 value point change on v_2. In other words if, w_1=0.6 and w_2=0.4, then a decrease of 1 point on v_1 is exactly compensated for by an increase of 1.5 on v_2. For any decrease in criterion v_2 from v_2^{init} to v_2^{fin}, a compensatory increase in v_1, v_1^{comp} can be determined by:

$$v_1^{comp} = v_1^{init} + (w_2/w_1) \times (v_2^{init} - v_2^{fin}) \qquad (3.2)$$

Where one of the criteria (say v_2) was derived from a monetary attribute (say x_2, e.g. profits) the implied monetary trade-off value of v_1 can be determined. If the value function were linear then, the value difference $v_2(x_2^{max}) - v_2(x_2^{min})$, arises from the attribute difference $(x_2^{max} - x_2^{min})$, and:
the monetary value per unit change in v_2 = $(x_2^{max} - x_2^{min}) \,/\, (v_2(x_2^{max}) - v_2(x_2^{min}))$ = R k,
and thus a unit change in v_1 will correspond to a monetary value of (w_2/w_1) x R k.

This trade-off information can provide useful feedback to the group(s), who might wish to re-adjust their weights. In addition, the monetary 'benefit' of choosing one scenario over another can be calculated using (3.2). If the value function were non-linear, a restricted range of values should be used (say corresponding to 20% of the score range), and the results will be approximate (see Section 7.3.2)

Another useful way to examine the scenarios is by looking at the '***value paths***' (e.g. Figure 3.5a), which show the simultaneous performance of all scenarios on all criteria at a chosen level of the value tree. This can help to point out where, for example, a scenario has the highest score on an aggregate level, but performs very poorly for one criterion (or one group). Another scenario, which performs slightly worst at an aggregate level but is not worst for any one criterion or group, may well be a better compromise solution. With more criteria and scenarios, this format is less useful. The value path idea can be concisely summarised and represented in bar graph form, where the ***relative contribution*** of each lower level (or whatever chosen level) criterion is displayed (e.g. Figure 3.5b) as part of its overall score. The latter figure immediately tells us that Scenarios 4 and 5 have very similar overall scores, but for very different reasons (Scenario 5 is perhaps more 'balanced').

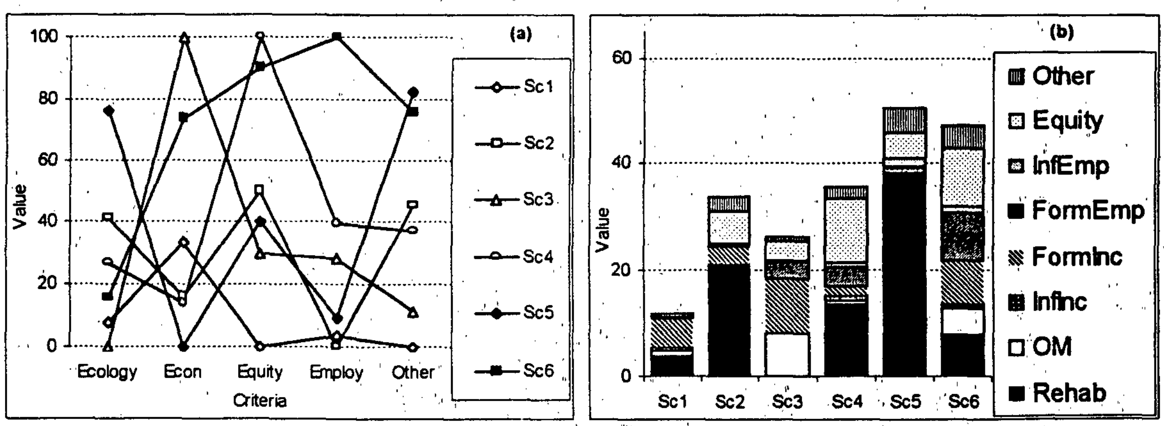

Figure 3.5. Value path (a) and relative contribution graphic (b) as feedback to groups.

3.5 Robustness and sensitivity

The facilitator/analyst would design appropriate analyses to test for sensitivity of any outcome to changes in weights and scores or other assumptions e.g. increase and decrease weights and scores by 10%. These would be reported back to the group(s) for comment, and possible adjustment. If two scenarios both had a high aggregate score, but one was robust to changes it would probably be preferable to one which was sensitive. VISA and the software described in Chapter 10 allow one to interactively change weights (or scores) and view the effect this would have on aggregate scores at any level of the value tree. VISA also allows one to compare the performance of two criteria at a time in order to view the 'efficient frontier'. The efficient frontier and weight sensitivity graphs can also be created in Excel.

The facilitator/analyst could design ways to analyse any imprecision which may have been included in the scores or weights (e.g. using linear programming or other software such as WINPRE). The analyst might also consider forming and analysing a larger set of scenarios (a background set) from the scenario elements, and using the scoring and weighting information see if other alternatives should be considered (using, for example, filtering techniques, multivariate statistical techniques, goal programming).

3.6 General guidelines

This chapter is intended to be reasonably stand-alone, and easy to assimilate. This has necessitated leaving details for other sections. It is important, however, that reference is made to various other sections of the report for these details, and for guidance about implementation. For the most part further theoretical and practical details are in Sections 2.1.1 to 2.1.3, and Section 2.4.1, examples of application in Chapter 7 to Chapter 9, and implementation hints in Section 6.3. Specific references are:

- **Criteria and Value trees**: The reader is referred to Section 2.1.1 regarding the development of criteria and value trees.
- **Weights**: The reader is referred to Sections 2.1.3, 2.4.1 and 6.3.5 for guidelines to ways of eliciting weights, the underlying concepts, and possible ways to avoid pitfalls.
- **Scores**: The reader is referred to Section 2.4.1 for guidelines to value measurement.
- **Role of the facilitator/analyst**: The reader is referred to Section 6.3.1 regarding the role of the SBPP/MCDA facilitator/analyst.
- **Participants**: The reader is referred to Section 6.3.4.
- **Time**: The reader is referred to Sections 6.3.2 and 6.3.4 regarding the workshop and time requirements of the SBPP/MCDA process.
- **Technology**: The reader is referred to Section 6.3.3 for further comment regarding the appropriate use of technology.

Appendix 3.1. Outline of the 'full' SBPP

In most real world situations it would be impossible to implement the full Scenario Based Policy Planning (SBPP) approach as originally developed in Stewart *et al.* (1993), and Stewart and Scott (1995). Consequently a simplified approach has been used and reported here. For completeness the full approach is summarised in Table 3.1 (some wording has been adapted from the original).

The number of scenarios generated in the background set may be large (see Stewart *et al.*, 1993, Table C1, page C7) in any real world setting and the method requires that consequences be determined for all of these for the filtering stage. Consequences which may be modelled might include financial and hydrological consequences. Other consequences (e.g. ecological, social) would not easily be modelled, but 'surrogate objectives' could be used (e.g. low flow levels as an aquatic ecology objective, employment numbers as a social objective). Objectives resulting from complex interactions of attributes would have to be ignored when filtering out a foreground set. As an example of the numbers of scenarios involved, if 7 scenario elements were defined (e.g. the seven land-uses in the Sand River example), the extended centre point design would generate 43 background set scenarios (modelling the hydrological consequences of only eight scenarios proved to be problematic within the time frame of the Sand River catchment planning project).

The process requires that the group defines (a) scenario elements, (b) relevant consequences, (c) attributes, (d) criteria, (e) objectives and surrogate objectives. The demands on the group are fatiguing, as it is difficult to explain and understand the differences between these, and in fact (b), (c), (d) and (e) may well involve the same concepts. The fatiguing effect on the group is particularly relevant as they would subsequently still be required to score the foreground set, give weights to criteria, and possibly go through several iterations.

For some practical applications therefore, particularly where time was a severe constraint, a simpler approach was required, which bypassed the formation and analysis of a background set of scenarios.

Table 3.1. The full SBPP process. Shaded blocks represent the stages carried out in the simplified form.

1.	**Define scenario elements**, their ranges and a few (say 4) discrete levels of each element	Analyst
2.	**Generate a background set** of scenarios formed by feasible combinations and using an extended centre point factorial design	Analyst
3.	**Select attributes and criteria** to describe and evaluate scenarios	Facilitated Group
4.	**Evaluate the consequences** of the background set of scenarios	Models
5.	**Filter out the foreground set** using randomly generated weights for the objectives, generally expressed in terms of the measurable attributes; keep the scenarios most frequently in the top 7 (from 1000 iterations).	Analyst
6.	**Assess the foreground set** (using standard MCDA techniques) using the criteria identified by each group	Facilitated Group
7.	**Explore** options for consensus	Facilitated Group
8.	Stop if reasonable consensus achieved; otherwise remove some scenarios from the foreground set, and add others (a) directly from the background set; or (b) by interpolation between scenarios in the background set; or (c) by redefinition of scenario elements and/or ranges.	Analyst, Group

Chapter 4. Links between SBPP/MCDA and environmental legislation

There are several national laws and policies (Table 4.3) which explicitly require the balancing of economic, ecological and social issues in decision making, and/or subscribe to the goal of 'sustainability'. Regardless of the exact terminology used, these policies or laws imply that trade-offs need to be made between various societal goals. The aim of this chapter is to highlight the conceptual and operational links between the SBPP and MCDA processes and tools described and developed elsewhere in this report and legislation or policies, and where possible, their mode of implementation. The bulk of the chapter deals with the National Water Act and various aspects of its implementation, but other Acts are also briefly discussed.

4.1 National Water Act

> The purpose of this Act is to ensure that the nation's water resources are protected, used, developed, conserved, managed and controlled in ways which take into account amongst other factors-
> a) meeting the basic human needs of present and future generations;
> b) promoting equitable access to water;
> c) redressing the results of past racial and gender discrimination;
> d) promoting the efficient, sustainable and beneficial use of water in the public interest;
> e) facilitate social and economic development;
> f) providing for growing demand for water use;
> g) protecting aquatic and associated ecosystems and their biological diversity;
> h) reducing and preventing pollution and degradation of water resources;
> i) meeting international obligations;
> j) promoting dam safety;
> k) managing floods and droughts,
> and for achieving this purpose, to establish suitable institutions and to ensure that they have appropriate community, racial and gender representation. NWA, 1998, Chapter 1, 2.

It is evident from the purpose of the Act quoted in the box above and from numerous sections within the National Water Act (NWA, 1998) that decision makers are required to make trade-offs between different issues at various levels (national, provincial and water management area levels) and at various stages. In brief, the implementation process involves:

1) the determination of the ecological management class of the resource (Table 4.1),
2) the determination of a Reserve for basic human and ecosystem needs which is appropriate to the ecological management class,
3) the determination of resource quality objectives (appropriate to the class and Reserve), and
4) the formulation of catchment management strategies and water allocations which will help to achieve the desired class, Reserve and resource objectives (Figure 4.1).

Each of these stages is essentially a multi-criteria decision problem involving trade-offs between the goals of maintaining ecological integrity and promoting economic growth and social equity. Each stage is discussed in more detail below where relevant. The way the NWA has been interpreted and / or is being implemented is indicated in Figure 4.1.

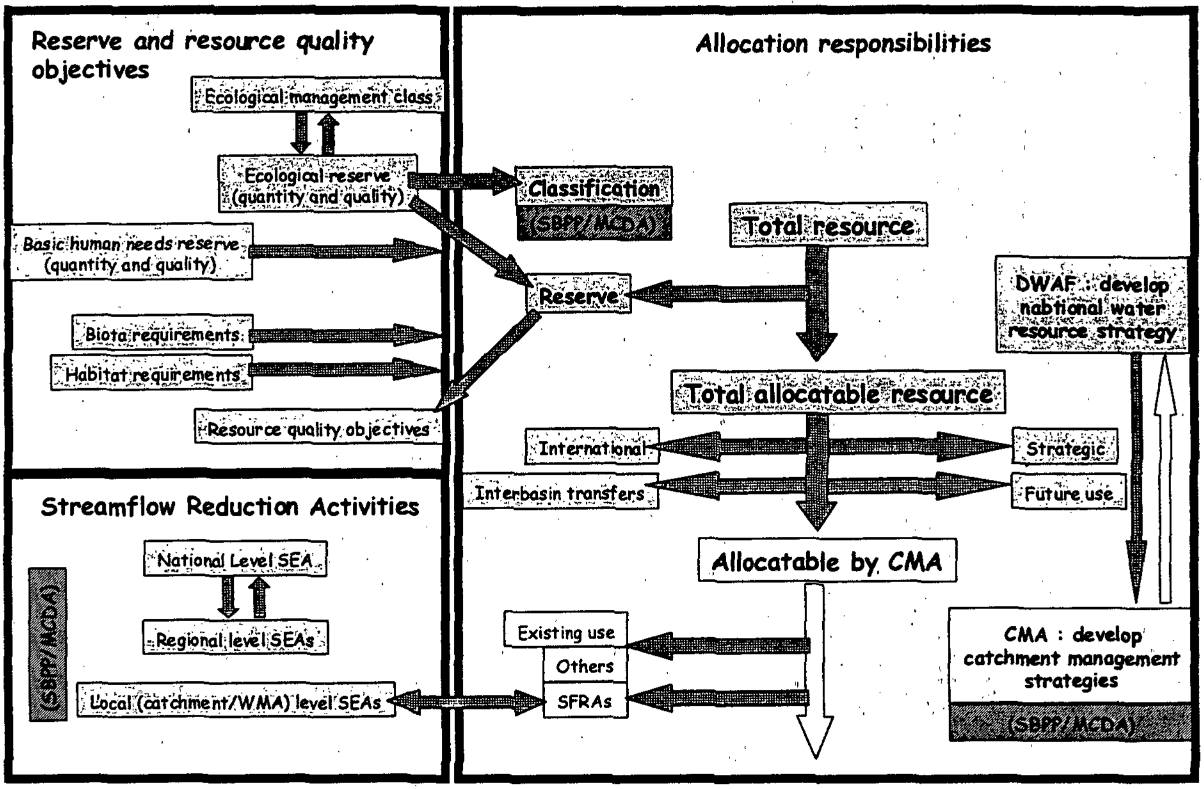

Figure 4.1. Allocation responsibilities and processes under the NWA. Refer to text and Page vi for acronyms. Areas where SBPP/MCDA could provide support are indicated in cross-hatched boxes.

4.1.1 Classification of the resource[4]

Firstly, all 'significant' water resources (i.e. river reaches, rivers, wetlands, estuaries, groundwater) need to be classified into an ecological management class (Table 4.1). When established, catchment management agencies will undertake this process. Significant refers not to 'importance', but rather to the geographic extent of the water resource unit for which a class, the Reserve and resource quality objectives need to be defined. This is presently dependent on the level of accuracy required for the determination of the Reserve, in turn dependent on the 'importance' of the resource, and could range from the quaternary catchment level (for a desktop estimate) to the level of a river reach. Slightly different processes have been followed for different types of water resources, but are presently being integrated.

The implementation process has resulted in the definition of six present ecological status classes (A-F) ecological, social and economic importance and sensitivity categories and, finally, four ecological management classes (EMC) which reflect different levels of protection (Table 4.1). The chosen EMC for a water resource, needs to 'satisfy the water quality requirements of water users as far as is reasonably possible, without significantly altering the natural water quality characteristics of the resource' (NWA, Chapter 3, Part 1, 12.2.b.ii). In other words, trade-offs need to be made between use and conservation. It is envisaged that the EMCs will at a later stage be combined with classifications for 'fitness for use' for different users (domestic, recreation, irrigation, stock watering, aquaculture) to give finally only three classes of resources (Special, General, 'Hard-working').

[4] Taken from DWAF 1999a, b, c, d.

Table 4.1. Ecological Management classes (EMC) for water resources.

EMC	Description
A	*Unmodified, natural* - the natural abiotic template should not be modified. The characteristics of the resource should be completely determined by unmodified natural disturbance regimes. There should be no human induced risks to the abiotic and biotic maintenance of the resource
B	*Largely natural with few modifications* - only a small risk of modifying the natural abiotic template and exceeding the resource base should be allowed. The risk to the well-being and survival of intolerant biota (depending on the nature of the disturbance) may be slightly higher than expected under natural conditions
C	*Moderately modified* - a moderate risk of modifying the natural abiotic template may be allowed. Risks to the well-being and survival of intolerant biota (depending on the nature of the disturbance) may generally be increased with some reduction of resilience and adaptability at a small number of localities
D	*Largely modified* - a large risk of modifying the abiotic template and exceeding the resource base may be allowed. Risks to the well-being and survival of intolerant biota (depending on the nature of the disturbance) may generally be allowed to increase substantially with resulting low abundance and frequency of occurrence

In the interim stage of implementation, the classification of the resource and the determination of the Reserve will be done at four levels of detail; the desktop, the rapid, the intermediate and the comprehensive assessments, depending on the 'priority of the resource'. Priority has been determined by assessing present and future levels of use.

- The ecological flow component of the Reserve is required for planning within the national water balance model. Available information is used to determine the ecological importance and sensitivity of the resource, which gives the 'default' EMC. This can be moderated by an assessment of the present ecological status of the resource, using available information, and may also take into account the practicality of restoration. This has been termed the 'desktop estimate'.
- In the rapid assessment, the EMC will be based on a desktop/workshop determination of the present ecological status and ecological importance and sensitivity using available information. The resulting EMC will be whichever is higher, and may be further upgraded by modifiers (e.g. RAMSAR sites must be class A).
- In the intermediate assessment, the present ecological status becomes the 'default' EMC which is upgradable by the ecological importance and sensitivity. Note that all class E and F status resources are upgraded to at least a D class EMC. A field social importance assessment may modify the designation of the EMC. The ecological implications of different EMCs will be evaluated to allow the selection of an acceptable scenario (i.e. EMC).
- In the comprehensive assessment, the present ecological status becomes the default EMC upgradable by the ecological importance and sensitivity (as for intermediate). The comprehensive assessment requires an assessment of the social importance and economic importance of the resource. It allows for stakeholder participation and 'scenario analysis' to assess the effect of a chosen EMC on water availability, allocation etc. and therefore on people dependent on, or with a stake in the resource. The implications of different EMCs will be evaluated to allow the selection of an acceptable scenario (i.e. EMC).

Tools for evaluating social and economic importance are discussed in the documentation and are referred to later. The processes and tools for integration of the ecological, social and economic ratings have not been defined, nor those to be used in the 'scenario analysis'. Given the associated levels of uncertainty, the level at which classification and consequent reserve determination takes place therefore proceeds from the most precautionary in terms of maintaining ecological integrity (desktop: ecological importance determines class) to the least (comprehensive: social and economic issues also play a role).

The classification of the resource therefore requires (at various levels) the prior determination of the ecological status, importance and sensitivity of the resource and the social and economic importance. Both for rivers and estuaries, the formulation of status and importance classes has been a process of forming various indices (e.g. species diversity) and aggregation rules for these indices (e.g. max-max, weighted summation, max-min etc.). At present, therefore, the classification 'rules' appear to be as reflected in Table 4.2. The development of indices and aggregation rules required is clearly a multi-criteria problem. The authors have been involved in the development of indices based on an MCDA approach (e.g. Stewart *et al.*, 1997), and in various practical applications (e.g. Lamberth and Joubert, in prep, Turpie, 2000). The team involved in developing the estuarine indices consulted to some extent with the authors, and have incorporated some of the suggestions made (Turpie, 2000).

Table 4.2. Resource classification for various levels of Reserve determination.

Level of assessment	Primary determinant	Result	Secondary determinant	Result	Modifiers	Result
Desktop	Desktop EI&S	→DfEMC	+PES	→DEMC	+*fn*(desktop PES)	→EMC
Rapid	Workshop PES	→DfEMC	+ EI	→DEMC	+*fn*(modifiers)	→EMC
Intermediate	Workshop PES	→DfEMC	+EI+*fn*(modifiers)	→DEMC	+*fn*(brief SI) +*fn*(scenario analysis)?	→EMC
Comprehensive	PES	→DfEMC	+EI+*fn*(modifiers)+*fn*(SI)	→DEMC	+*fn*(scenario analysis, stakeholder input)	→EMC

DfEMC = Default Ecological Management Class DEMC = Desired Ecological Management Class
AEMC = Achievable Ecological Management Class MC = Management Class
PES = Present Ecological Status EI&S = Ecological Importance and Sensitivity
SI = Social Importance EI = Economic Importance
Modifiers include protection status such as if the resource is a RAMSAR site, or part of a National Park etc.

4.1.2 Determining the Reserve

Secondly, continuing from the designation of an EMC, and on the determination of basic human needs, the Reserve is determined in terms of water quantity and quality at the desktop, rapid, intermediate or comprehensive level. This will be a national level function until catchment management agencies are established. Basic human needs in terms of quantity and quality need to be established, and 'worked back' to what is required in the river in order to supply this. For a comprehensive ecological reserve determination for rivers, relatively well established techniques for instream flow requirements are used such as the BBM (King and Louw 1998) and DRIFT (Brown and King, 1999). For desktop and rapid assessments use will be made of the 'Hughes curves' (DWAF 1999d). These are based on the translation of a composite index into values for percentages of mean annual runoff to be allocated.

In the intermediate and comprehensive Reserve determination, 'selected future scenarios' (i.e. possible EMCs) will be assessed and the ecological, social and economic implications evaluated to allow the selection of an acceptable scenario (MC) on which the Reserve will be based. Ecological, social and economic considerations are also all to be considered in the formation of catchment management strategies (see Section 4.1.4). Once the Reserve has been established, allowances are made for international and strategic water resources, for interbasin transfers and for 'future use'. This is a national level function (i.e. these are determined prior to a catchment management agency being allowed to allocate any water).

4.1.3 Determining resource quality objectives

Thirdly, the EMC and Reserve pre-determine in general terms the resource quantity and quality objectives, which then need to be specified in detail. It is specified that a 'balance needs to be sought between the need to protect and sustain water resources on the one hand, and the need to develop and use them on the other.' (NWA, 1998, Chapter 3, Part2). The objectives also may relate to 'the regulation or prohibition of instream or land-based activities which may affect the quantity of water in or quality of the water resource' (NWA, 1998 Chapter 3, Part 2, 13.2.g).

4.1.4 Catchment management strategies and water allocation

Fourthly, the catchment management agencies (CMAs) are responsible for water allocations (licensing) for allocatable water (i.e. after allowing for the Reserve, strategic and international obligations) within their water management area. The water allocations need to conform to the catchment management strategy (CMS) established by the CMA. The CMS is in fact the means by which the EMC, Reserve, and resource quality objectives are achieved. In developing them, CMAs need to consult with interested stakeholders and those whose activities might affect the water resource in order to develop a CMS which *:

1. Sets out the strategies etc. of the CMA for the protection, use, development, conservation, management and control of water resources within the WMA.
2. Takes into account the *management class* of the water resource and the resource *quality objectives.*
3. Takes into account geology, demography, land-use, climate, vegetation, waterworks within the WMA.
4. Contains water allocation plans, which must set out the principles for allocating water, taking into account:
   - Existing lawful water users
   - The need to redress the results of past racial and gender discrimination
   - Efficient and beneficial use of water in the public interest
   - The socio-economic impact
     - Of the water use or uses if authorised
     - Of the failure to authorise the water use or uses
   - The likely effect of the water use to be authorised on the water resource and other water users
   - Investments already made and to be made by the water user in respect of the water use in question
   - The strategic importance of the water use to be authorised
   - The quality of water in the water resources which may be required for the Reserve and for international obligations
   - The probable duration of any undertaking for which a water use is to be authorised
5. Enables the public to participate in managing the water resources within the WMA.
6. Takes into account the needs and expectations of existing and potential water users.
7. Sets out institutions to be established.
8. Is not in conflict with the national water strategy and other national and regional plans prepared in terms of any other law.

* National Water Act 1998, Sections 9, 23, and 27.

Streamflow reduction activities and strategic environmental assessment

Part of the water allocatable by a CMA may go to activities which reduce flow through the interception of runoff and groundwater (streamflow reduction activities or SFRAs) and measures are being developed to assist in the process of licensing SFRAs. Presently only commercial forestry has been classified as a SFRA, but any activity which 'is likely to reduce the available water in a water course to the Reserve, to meet international obligations, or to other water users significantly' (NWA 36(2)) may be declared as such. Until CMAs are established, licensing will continue to be performed by DWAF.

It has been recognised that individual applications and their impacts on allocatable water, social, economic and environmental values need to be assessed within a strategic framework. This is being promoted through a national and subsequent regional and local strategic environmental assessment (SEA) (DWAF, 1999e). The SEAs are expected to provide amongst other things improved negotiation and decision support tools and links to provincial environmental (and other) management plans (see Sections 4.3 and 4.3.1).

The SFRA will be evaluated in comparison with alternative land uses, and in order to do so consistently 'Principles, criteria, indicators and standards' have been established by DWAF (DWAF, 1999e). It is envisaged that decisions will then be based 'both on the grounds of scientific assessments and on the outcome of debates amongst stakeholder representatives' (DWAF, 1999e). The 16 criteria developed by DWAF to apply to SFRA decisions include many of the criteria used within applications of SBPP/MCDA as discussed in this report, for example (DWAF, 1999e):

- the effect on (instream, riparian and terrestrial) habitats and biota
- the effect on water quality
- the economic effects
- the employment and income distribution effects
- the effects on human capital
- the effects on social and community life
- the effects on infrastructure development
- the effect on cultural values and heritage

It is presumed that a scoring system is being developed in order to be able to implement the use of these criteria, but details are unavailable at this stage.

Clearly, SBPP/MCDA processes and tools would be appropriate in supporting SFRA decisions. SEAs are also discussed in Chapter 5.

4.2 Links to MCDA

There are various stages and levels in which the SBPP/ MCDA processes and/or various MCDA tools could be used in the implementation of the NWA. These are discussed below. Various other decision-support methods have been used and promoted within the implementation process. These methods are contextualised and the stages of decision-making to which they are relevant are discussed in Chapter 5.

Formation of status and importance indices and their aggregation

The ecological status, importance and sensitivity, social importance and economic importance of a resource have been (or will be) defined through the use of various indices, usually made up by aggregating various 'sub-indices' (e.g. see Chapter 9 for the formation of the estuarine ecological status index). This use of various multi-criteria methods within this process could help to ensure some 'validity' to the outcome through:

- considering the ***preferential independence*** of criteria (Section 2.1),
- defining the discrete criterion or index levels in such a way that the scales have an **interval** interpretation (e.g. see Section 2.1.1 Stewart *et al.*, 1997),
- using the ***swing-weighting*** concept to derive weights for 'sub-indices' to allow *appropriate* integration (Section 2.4.1).

For example, for rivers, the ecological status index (for the desktop assessment) has been formed by taking the mean of six scores, each on a scale of 0-5. The confidence of the specialist giving the score is also given on a scale of 0-4. A measure of 'confidence' is required in these sorts of assessments as well as in environmental impact assessments (EIAs), but it is not clear how this affects the resulting final score, if at all. However, at least for the rapid determination of the ecological importance and sensitivity of riverine ecosystems, 'the possibility of using confidence ratings as indicators of the relative weights of various determinants is ... receiving attention'. Confidence estimates, to more 'accurately' reflect their meaning, could be translated into intervals around the score given, and the final aggregate score therefore given upper and lower bounds.

For estuaries, the ecological status for the intermediate assessment has been formed by taking the weighted mean of a weighted mean of five abiotic indices, and four biotic indices (some of which were, in turn formed by aggregating sub-indices). The estuarine ecological importance index is the weighted mean of five indices, in turn formed by aggregating various sub-indices. The creation of a ***value tree*** proved invaluable in this process (Chapter 9) both as a visual cognitive tool (to comprehend all the various levels and aggregations) and to ensure coherence of the system.

Preliminary indices have already been established for the social importance rating. Prescriptions such as that they should not be subject to 'complex statistical' analyses, and that social and ecological issues 'should never be combined as a single mean, since they describe different and mutually exclusive aspects of importance' (DWAF, 1999d) are unhelpful and seem inappropriate, especially when no alternative is offered. However, it is true that the simplest systems are usually most appropriate and that care should be taken in any process where different indices are aggregated.

- In situations of true incomparability no decision can be made, otherwise, ***outranking*** methods (e.g. ELECTRE) which do not assume compensation and comparability could be used. We believe that outranking methods are, however, more complex, less accessible and less generally acceptable than the thermometer scale and swing weighting approaches we have used.
- In the end, the social and ecological ratings *must* be assessed simultaneously in a more-or-less structured way (which does necessarily require aggregation) in order to make a decision. Using appropriate tools in the creation of these indices can help to improve the quality of this comparison, making the comparison more transparent and explicit and avoiding potential theoretical errors (such as adding ranks).

Classification of the resource: integration of indices and scenario analysis

The classification of the resource involves the aggregation of indices in some form at any of the four levels of Reserve determination, in order to take into account ecological, social and economic issues. Care needs to be taken to ensure that this step does not mask the values and judgements underlying the process. Two factors are important.

Firstly, this means simply that where very low scores are hidden in aggregation, some sort of 'overriding rule' may be appropriate. For example, where one criterion has a value below a certain threshold, the final index value might take on this value rather than the mean. This approach has been followed for various indices (e.g. riverine and estuarine ecological status indices). Such 'decision rules' could easily be accommodated within the usual SMART approach (Chapter 3). Alternatively an outranking approach could be adopted, but it is our belief that this would have to be considerably simplified for application in this context (see comments about ELECTRE above).

Secondly, the interpretation of aggregate scores depends on the type of information which goes into the score. We illustrate this with an example from the 'rapid' PES index, which is based on the mean of scores on a 0-5 scale for six 'attributes'. The meaning of the scores is 'global' in that the same definitions apply to all six attributes, where 5 is interpreted as 'natural, unmodified' and 0 = 'critically modified'. The (unweighted) mean, as used, can only be interpreted as having an absolute meaning for translation into a PES category if:

1. the *range* from 0 to 5 is the same for each attribute,
2. and a score of, say 4, has the same *importance* across all criteria,
3. and if the '*gaps*' between each level (e.g. from 2 to 3, and from 4 to 5) have the same meaning.

As the same definitions apply across the criteria, it is likely that (1) is satisfied, and in the designing of the definitions for each score it is likely that (3) was reasonably satisfied. However, it is not clear that, for example, a score of 3 (i.e. Moderately modified from natural) for the criterion 'Flow' has the same importance/severity for PES as a score of 3 for the criterion 'Water quality'. In other words, the range 0-5 might well be the same as this is so defined, but the effect of that range on ecological status is not defined. A *swing weighting* or 'indifference' type of exercise could be applied in order to verify this (see Chapters 2.4.1 and Chapter 3).

Desktop scenario analysis of different management classes

With very little further effort required than is currently envisaged for the desktop and rapid determination of the Reserve:

- **'desktop' SBPP /MCDA** exercises could bc undertaken to allow for the integration of economic and social issues into the desktop and rapid classification processes.

Intermediate and comprehensive scenario analysis

For the intermediate and comprehensive analyses it is specified that there will be 'scenario analysis' of alternative management classes and associated Reserves. The documentation does not specify what is intended by the term 'scenario analysis'. From informal talks, it appears that the use of this phrase in South Africa does not imply the specific or formal comparison of the performance of scenarios on different criteria. Rather, it implies the presentation of results and consequences, and general discussion of these. In contrast, Australian literature on determining IFRs specifies the need for an 'informed trade-off process' (e.g. Young *et al.*, 1995). Given the requirement for stakeholder input, the necessary trade-offs to be made and the importance of any outcome, some formalisation would seem essential.

- the ***SBPP/MCDA process*** is geared to exactly this sort of problem, in providing aid in the ***construction of scenarios,*** in allowing the ***inclusion*** of tangible, intangible, quantitative and qualitative issues, and the inclusion of inputs from different stakeholders within a ***common framework***.

Development of Catchment Management Strategies

The process followed for the Sand River catchment (Chapter 7), could easily be adapted to more closely conform to the requirements of CMAs in formulating CMSs, and for comparing different water allocation plans. The reader is referred to Chapter 7, but briefly the approach could be to:

- Follow an ***overall SBPP/MCDA framework*** in order to
- construct catchment ***scenarios*** and identify ***criteria***, and
- use SMART to ***evaluate*** scenarios for each criteria, and to ***weight*** the criteria, and
- to assess sensitivity of outcomes to scores and weights etc.

Strategic Environmental Assessments

In essence, the Sand River catchment planning (Chapter 7) and Maclear land-use planning (Chapter 8) studies *were* SEAs, as they provided the strategic framework within which more detailed decisions and assessments could be made. Thus an SEA framework is essentially the same as an SBPP/MCDA framework (see also Chapter 5). As discussed, well developed techniques are readily available for use within the SBPP/MCDA framework, which could equally well be used within an SEA.

Reformulation of implementation process within an SBPP/MCDA framework

The entire classification and Reserve determination process as well as the development of CMSs could be reformulated within an SBPP/ MCDA framework (see Chapter 3). There are two phases, in particular, where SBPP/MCDA would be useful: the classification of the resource, and the development of CMSs, including allocation plans and SFRAs (Figure 4.1). Much of the implementation documentation refers to 'scenario analysis', 'mcaningful input from stakeholders' and the balancing of ecological, social and economic issues: these arc areas which SBPP/MCDA is designed to support.

4.3 Other legislation

In the formulation of CMSs and in allocating water, other legislation and the possible development plans required by them will need to be taken into account. These development plans will, in turn, need to take NWA requirements into account. Examples of such plans and legislation include:

- the local authorities' Integrated Development plans (Local Government Transitional Act No. 61 of 1995),
- the Land Development Objectives (Development Facilitation Act No. 67 of 1995),
- Environmental Management and Implementation Plans (National Environmental Management Act No. 107 of 1998),
- EIAs for certain changes in land use (Environmental Conservation Act No. 73 of 1989),
- the Conservation of Agricultural Resources Act (No. 43 of 1983),
- and the National Resources Heritage Act (No. 25 of 1999).

Relevant legislation is listed in Table 4.3 and some of these Acts are discussed below.

Table 4.3. Departments and legislation having relevance to SBPP/MCDA.

National Authority	Legislation / Policy	Implementation	Current approach & methods
Dept Water Affairs & Forestry	National Water Act No. 36 of 1998	Classify resource, determine Reserve, Catchment management strategies, Streamflow reduction activities	Indices: ecological, social and economic importance, status. 'Scenario analysis', Strategic environmental assessments
	Water Services Act No. 108 of 1997	?	
	National Forests Act 84 of 1998	?	
Dept Environmental Affairs & Tourism	National Environmental Management Act No. 107 of 1998	IEM, EMP, EIP	Mostly interpreted as requiring EIA in the 'traditional' sense
	Environment Conservation Act No. 73 of 1989 & Regulation 1182 of 1997 in terms of Section 21 of this Act	EIAs	Mostly interpreted as requiring EIA in the 'traditional' sense
Dept of Land Affairs		LandCare	?
Dept of Arts, Culture, Science and Technology	National Resources Heritage Act No. 25 of 1999		

4.3.1 National Environmental Management Act

In the preamble to the National Environmental Management Act (NEMA, 1998) it states that: '*...sustainable development requires the integration of social, economic and environmental factors in the planning, implementation and evaluation of decisions to ensure that development serves present and future generations...*'. Integrated environmental management (IEM) is promoted in the Act as the means of achieving sustainable development. The objectives of IEM in terms of the Act are to promote the principles of Section 2 which include that one should '*identify, predict and evaluate the actual and potential impact on the environment, socio-economic conditions and cultural heritage, the risks and consequences and alternatives and options for mitigation of activities*', and '*ensure adequate and appropriate opportunity for public participation in decisions that may affect the environment*'.

Some of the means of implementation are to '*prepare compilations of information and maps that specify the attributes of the environment in particular geographical areas, including the sensitivity, extent, interrelationship and significance of such attributes which must be taken into account*' and, as a minimum, to investigate the '*potential impact including cumulative effects, of the activity and its alternatives on the environment, socio-economic conditions and cultural heritage, and assessment of the significance of that potential impact*', and ensure that there is '*public information and participation, independent review and conflict resolution in all phases of the investigation and assessment of impacts*' and report on '*gaps in knowledge, the adequacy of predictive methods and underlying assumptions, and uncertainties encountered in compiling the required information*'.

In choosing alternatives, the '*best practicable environmental option*' should be chosen: this is defined as the option that '*provides the most benefit or causes the least damage to the environment as a whole, at a cost acceptable to society, in the long term as well as in the short term*'.

The 'Principles' of the Act place the emphasis on the promotion of the social and economic rights and basic needs of people, and states that '*environmental management must place people and their needs at the forefront of its concern, and serve their physical, psychological, developmental, cultural and social interests equitably*' while at the same time requiring that development needs to be '*socially, environmentally and economically sustainable*'. The requirements of sustainability therefore requires that the 'relevant factors' are considered: ecosystem disturbance and loss of biological diversity are minimised, environmental degradation is minimised, disturbance of cultural heritage landscapes and sites is minimised. A risk averse approach is promoted which takes into account the '*limits of current knowledge about the consequences of decisions*', and which distributes environmental costs fairly, and promotes the participation of '*all interested and affected parties in environmental governance*' and take into account their '*interests, needs and values*', and finally that the '*social, economic and environmental impacts of activities, including disadvantages and benefits must be considered, assessed and evaluated and decisions must be appropriate in the light of such consideration and assessment*'.

In terms of the Act, relevant national and provincial departments must prepare environmental implementation and /or management plans (EIPs and EMPs). These are meant to co-ordinate policies, plans and decisions of various departments. The EIPs need describe ways in which the department will ensure that any policy or plans comply with the principles mentioned above. EMPs must describe any policies or plans designed to ensure compliance, and co-operation by and with other departments.

The Act recognises the need for 'improving the quality of decision-making by giving interested and affected persons the opportunity to bring relevant information to the decision-making process' (NEMA, 1998, Chapter4, 22.1.c). The above has been interpreted as the *de facto* legislative requirement for 'traditional' EIAs as practised in South Africa. In other words, methods that evaluate and compare alternatives and their impacts are not regarded as appropriate unless they are clearly recognisable as the conventional South African EIA. Clearly SBPP/MCDA tools are relevant in comparing and evaluating impacts and choosing alternatives, and indeed, have advantages over EIA methods (Joubert *et al.*, 1997, and Gregory *et al.*, 1992). However, given the current wariness towards MCDA from the EIA fraternity, at the moment it may be more acceptable if certain MCDA tools are integrated within accepted EIA process (e.g. Joubert, 1998). The conversion of qualitative and semantic scoring in EIAs to quantitative scores to allow for integration is one obvious possibility for inclusion. However, there is resistance to this in particular. The assumption seems to be that people will assume some 'precision' when faced with a numeric rather than verbal score, and not attach due thought and caution to any decisions resulting. The 'dangers' of this may be far outweighed by the benefits of being able to explicitly weight and aggregate, rather than leaving this to an internal process, carried out by individuals after individual reports have been compiled (Joubert *et al.*, 1997). In addition, EIAs conventionally require some estimation of confidence in the scores given. As mentioned earlier, these could be converted to 'confidence intervals' around the numeric scores, implying an appropriate degree of imprecision. Where a final preferred option was consequently not apparent, this might also help to indicate where further detail were necessary.

4.3.2 Environment Conservation Act (Act No. 73 of 1989) Regulation under Section 21 (Sep, 1997).

In 1997, a regulation identifying (under Section 21) activities which have a substantial effect on the environment was promulgated. Besides identifying these activities, the regulation also specifies that the relevant authority may decide that the information in a scoping report is sufficient or that an environmental impact assessment needs to be done. The description of the environmental impact assessment process could equally be a description of an MCDA process i.e.:

' a) a description of each alternative, including particulars on-'

i) the extent and significance of each identified environmental impact; and ... '

' b) a comparative assessment of all the alternatives... '

4.3.3 National Forests Act (Act 84 of 1998)

The preamble to the Act states that natural forests and woodlands need to be *'conserved and developed according to the principles of sustainable management'* and that plantation forests play an important role in the economy, have and impact on the environment and that the economic, social and environmental benefits of forests need to be fairly distributed. It states that the purposes of the Act are to promote the *'sustainable management and development of forests for the benefit of all'* and to promote the sustainable use of forests for *'environmental, economic, educational, recreational, cultural, health and spiritual purposes'* (NFA, 1998, Chapter 1, 1.a.,d). In Chapter 2 of the Act the sustainable management of forests is promoted. This happens in several ways including the principles:

(a) natural forests must not be destroyed save in exceptional circumstances where, in the opinion of the Minister, a proposed new land use is preferable in terms of its economic, social or environmental benefits;
(b) a minimum area of each woodland type should be conserved; and
(c) forests must be developed and managed so as to-
- (i) conserve biological diversity, ecosystems and habitats;
- (ii) sustain the potential yield of their economic, social and environmental benefits;
- (iii) promote the fair distribution of their economic, social, health and environmental benefits;
- (iv) promote their health and vitality;
- (v) conserve natural resources, especially soil and water;
- (vi) conserve heritage resources and promote aesthetic, cultural and spiritual values; and
- (vii) advance persons or categories of persons disadvantaged by unfair discrimination

The Act also provides for development of *'criteria on the basis of which it can be determined whether or not forests are being managed sustainably'*, and indicators which may be used to *'measure the state of forest management'* which will take into account specific regional economic, social and environmental conditions (NFA, 1998, Chapter 2, 4.2.i.,ii). This would imply the use indices, which could benefit from an MCDA perspective.

4.4 Conclusions

The above discussions have tried to highlight areas within which either the SBPP/MCDA process, or specific MCDA tools or both, could be applied to support the implementation of current legislation and policy directions. In summary therefore:

- SBPP/MCDA offers a *framework* for developing and evaluating alternatives as required by the acts
- MCDA offers theoretically sound and broadly accessible tools with which to define criteria contributing to overall objectives, and with which to evaluate alternatives
- MCDA offers theoretically sound and broadly accessible tools (e.g. SMART) for evaluating alternatives
- MCDA offers the opportunity to include a wide range of inputs of different types (qualitative and quantitative) and from different stakeholders, helping to ensure a holistic and transparent assessment.
- MCDA offers tools for developing coherent and justifiable scoring systems for indices.

Chapter 5. Decision-support methods and their potential roles in integrated water resource management

Considering the wide array of frameworks, protocols, processes, methods, tools, models etc. all included under the broad umbrella of decision support for integrated water resource management (IWRM) it is relevant to attempt to contextualise some of these methods within the various stages of a generic decision making process. This process and the activities which require support within each stage might be defined as:

1. Acquiring of information
2. Problem structuring
   - providing a framework
   - identification of alternatives, criteria, stakeholders, constraints
   - supporting the participation of stakeholders
   - supporting the inclusion of societal values, tangible, intangible, qualitative and quantitative,
   - supporting the process of obtaining and including necessary data and information,
3. Evaluation of and choosing between alternatives
   - Visualisation
   - Ranking and scoring (aggregation, integration, discussion)
   - Supporting the trade-off process
4. Making provisional decisions (negotiation, consensus)

Both the overall process of decision-making and the activities within the broad stages can be supported in various ways by 'decision support' tools. In this chapter we briefly mention some of these tools, and attempt to illustrate which stages of a decision process they may or may not support. There are many other methods not mentioned here, and phases not addressed (e.g. arbitration). We concentrate on those methods which we have come across in South Africa, particularly those which are being actively promoted within IWRM and the implementation of the NWA. The following approaches have been specifically mentioned in the documentation relating to the implementation of the NWA and investigations into the use of these methods are being undertaken in South Africa and are being funded by various national and international organisations:

Risk assessment
Monetary evaluation of ecosystem services (as part of Reserve determination)
Strategic environmental assessments (SEA)
The objectives hierarchy protocol (OHP) and associated methods

Other methods/tools/processes relevant to one or more of the decision-making stages are:

Participatory and rapid rural appraisal (PRA and RRA)
Cost benefit analysis (CBA)
Hydrological modelling tools (ACRU, etc.)
Instream flow requirement methods (BBM, DRIFT)

Software considered as 'decision support systems' include:

Integrated Catchment Information System (ICIS)
Integrated Water Resource Management Planning (IWR-PLAN)
Conservation Planning (C-PLAN)

Part of the intention of the authors is to clarify in which ways these methods could be complementary, rather than 'in competition', mainly in order to avoid the continuous re-invention of the wheel.

5.1 Problem structuring methods or frameworks

Four of the decision support tools mentioned in this chapter provide, or claim to provide, an overall framework within which multi-issue, multiparty decisions could be supported. These are CBA, SBPP/MCDA, OHP, and SEA. Some of these 'frameworks' also contain 'evaluation' tools, and/or the evaluation and structuring stages are not separable. Thus, CBA is an economic framework which to a certain extent defines the problem structure and the evaluation tools. SBPP/MCDA is both a framework and a method of evaluation (see Chapter 3). Note that methods other than those mentioned in Chapter 3 are included in the term MCDA such as, for example, goal programming (see Chapter 2.4.2). The OHP framework to a certain extent (through defining thresholds) pre-supposes a goal orientated (possibly MCDA) approach to evaluation. PRA is an approach to involvement with communities which includes specific methods for defining alternatives and evaluating these (e.g. mapping and matrices).

Some of these processes are very similar and one could probably interchange between them, or between different stages of them, without anyone really being aware of this (creating what is termed a multi-methodology). Particularly interchangeable in terms of providing a framework, rather than of internal tools, would be MCDA, OHP and SEA. In other cases only a unidirectional interchange is possible. For example, one could include the results of a CBA or an economics valuation within a MCDA or SEA, but one could not really include an MCDA evaluation within a (real) CBA.

5.1.1 SBPP/MCDA

The reader is referred to, in particular, Chapter 3, Figure 3.1, Table 3.1 and Stewart *et al.* 1997.

5.1.2 Cost-benefit analysis

Various forms of cost-benefit analyses are often applied to public sector planning. This can be viewed as another approach to (or "school" of) MCDA, in the sense that a number of different benefit and cost measures (or "criteria") will be taken into account. The primary difference between CBA and other approaches to MCDA is that in the former all costs and benefits of whatever nature are translated into equivalent monetary amounts prior to starting on the comparison of alternatives. In contrast to this, MCDA starts by comparing alternatives directly with each other in terms of each criterion, some of which may be very qualitative in nature, i.e. comparing like with like directly. Only once these within-criterion comparisons and the strength of concerns about them are well understood does MCDA proceed to the aggregation step.

In assessing, for example, different land-use scenarios, CBA would require that all costs and benefits be converted into monetary terms. This would potentially include externalities, effects and values not normally valued in the market through the use of hypothetical market techniques. The choice between different land-use combinations would then be determined by the benefit/cost ratio, the difference between aggregated net present costs and benefits or the internal rate of return. The financial or economic implications could include:

- The impacts of soil erosion on the net present value (NPV) of income from different land-uses.
- The impacts of decreased water quality on the costs of water treatment or health treatment.

- The impacts of increases in alien vegetation which could be measured in terms of the effect on water yield of the catchment. The change in water yield in the catchment could in turn be measured in terms of opportunity cost.

There are, however, some fundamental problems in reducing all criteria to monetary equivalents at the outset, especially for criteria of a more qualitative nature such as sociological, environmental or aesthetic goals. The inclusion of important social and environmental costs and benefits in CBA would require the use of such techniques as hedonic pricing, contingent valuation, travel cost etc., typically assessing "willingness-to-pay". Unfortunately, however, responses to such assessments are likely to be strongly culturally dependent, as well as influenced by availability of disposable income. Where planning involves diverse stakeholder groups, therefore, comparability of the financial equivalents may be difficult to justify, as results may be biased in favour of wealthier stakeholder or interest groups (who may be "willing to pay" more to secure their preferred outcomes). The problems associated with using some of these tools (including that they are non-participatory, complex and data-intensive) have been discussed elsewhere, while the theoretical basis of CBA itself rests in neo-classical economics foundations not necessarily appropriate in a developing world mixed economy.

Rather than trying to value in monetary terms the possible quality of life or ecosystem benefits of choosing a more 'environmentally friendly' option, some have recommended that these issues be left for qualitative comparison (e.g. Pearce, 1983). This could in effect mean using MCDA, or simply asking the question: 'over the next generations, will the value of the return to natural land-cover, the preservation of this habitat diversity etc. be worth R X million in lost financial returns'. The latter leaves the subsequent trade-offs to the decision-maker, while the use of MCDA offers the opportunity to include the stakeholders' preferred trade-offs as information available to the decision-maker. At the end of the day, the results of MCDA will imply some form of acceptable trade-off between financial and other criteria. At the conclusion of the analysis it may be useful to make these implied trade-offs explicit, as a consistency and reasonableness check. In fact we argue that the application of MCDA methods, especially value measurement, to a range of outcome scenarios may be a most effective means of performing contingent valuation (see, for example, Section 7.3.2 and 8.1.2). The principles underlying MCDA, however, are that financial equivalents should emerge from the process of decision analysis, rather than to be imposed from the start as expert inputs.

Conversely, the derivation of such monetary values over the last few years has helped focus the attention of decision-makers on the potential economic consequences of environmental degradation in a way not achievable through qualitative approaches. In addition, the theories, ideas, concepts and problems with which CBA researchers and practitioners have had to grapple, are invaluable and could usefully be incorporated into other approaches (e.g. temporal scales, types of value etc.). CBA is of course, the appropriate method for calculating financial and 'monetisable' consequences of scenarios. For more detailed assessments of CBA and associated tools see Fischhoff *et al.*, 1983, Pearce, 1983, Joubert *et al.*, 1997 and references therein.

A further potential problem in using monetary equivalents as a means for comparing alternatives relates to preferences across time, i.e. when costs or benefits accrue over a substantial period of time. Money can always be invested and recovered at a later date, having earned some interest. It makes sense, therefore, to use NPV calculations to compare different money streams over time. The temptation is to apply the same principle to the monetary equivalents of other costs or benefits. There is a fundamental problem, however, in that environmental or sociological benefits cannot be "banked" now for later use, so that there is no immediate justification for applying the typical geometric discounting used in financial calculations.

It is no doubt true that future costs and benefits will always weigh less on decision makers than the immediate. It has been demonstrated, however, that other forms of non-geometric discounting may be more relevant to non-financial criteria (for example, a weighting proportional to a function of the form $1/(1+at)^b$, where t represents the time from the present). Such functions may exhibit a high rate of discounting over the first few years, but will eventually place greater weight on very long run concerns than that of any geometric discounting, even as the interest rate used tends to zero. (See Stewart, 1998, for some discussion.)

Within the MCDA context, if there are serious concerns over comparing short-, medium- and long-term benefits and costs, it would probably be advisable to treat such concerns in the short-, medium- and long-term as separate criteria. When the analysis is complete, the implied weights on different time horizons can, as with monetary trade-offs, be checked for consistency and reasonableness.

5.1.3 The Objectives Hierarchy Protocol

A current project funded by WRC is aimed at developing protocols for CMAs, and is apparently mostly based on the Objectives Hierarchy Protocol (OHP) (Rogers and Bestbier, 1997, Bestbier and Rogers, 1997). OHP developed within the Kruger National Park Rivers Research Programme, and is very similar in structure to MCDA in some respects. However, it differs in its overall objectives and in some details. The purpose or objectives of the OHP which are relevant to this chapter could be summarised as fourfold:

a) to co-ordinate and integrate management, research, institutional and conservation goals
b) to facilitate the process of deciding on measurable goals which can be monitored
c) to facilitate stakeholder input
d) to aid decisions about future developments - i.e. do they help achieve the stated goals

The first two objectives could clearly be fulfilled by the OHP as described, particularly in its provision of a 'cognitive map' of the links between the hierarchy of overall broad level objectives, specific goals and the management, conservation and research aspects associated with these. In implementing the first objective, the OHP appears to be filling a niche not addressed by other approaches. Its success in achieving the third objective, as with other participatory methods (MCDA, RRA, PRA, etc.), would depend more on the facilitator than on the protocol itself. With regard to the fourth objective it is unclear how the lower level measurable goals are weighed up against each other in order to decide if an improvement in one is 'worth' a reduction in another. This would be especially problematic where, for example, large social benefits associated with an option could have severe environmental costs.

The Sand River project Phase I report ended with the construction of a preliminary OH, for the future implementation of the various recommendations and further research (Chapter 7, Pollard *et al.*, 1998, pg. 264). Its role is essentially an auditing system: on the simplest level to tick off 'have we remembered to address this issue' and at the deeper level, once goals are defined, to assess whether developments move towards or away from the goals. As a means of *choosing* between competing options with conflicting benefits, it would seem limited, and therefore preferable to use the more established techniques such as MCDA, which could be blended within the OH.

5.1.4 Strategic Environmental Assessment

The problems associated with SFRAs are being analysed within an SEA framework via a current project (DWAF and CSIR, funded by the UK Department for International Development), and the approach is also being promoted in other contexts. SEA is 'at present a generic term that is not yet linked to a clearly established methodology' (DWAF, 1999f) and there is no definite approach either internationally or locally. However, it is being promoted at various levels and has been accepted as one of the 'established list of integrated environmental management tools' (DWAF, 1999f). SEA attempts to integrate environmental, social and economic factors into development policy making at appropriate spatial scales. Although there is no methodology attached, the concept of SEA in South Africa includes that it should (DWAF 1999f,g, CSIR 1999):

- Be flexible and adaptable
- Be participative and 'transparent'
- Present alternative scenarios within the context of an overall vision
- Set criteria for levels of environmental quality

Its key emphasis has been defined as 'choosing the best way to achieve objectives' through considering alternatives early on in the decision-making process (DWAF, 1999e). An example of an SEA process given in CSIR (1999) is as follows (abbreviated):

- Identify broad policy, plan or programme alternatives and their purpose.
- Identify vision and strategic issues.
- Identify 'sustainability' objectives, criteria and indicators.
- Identify opportunities and constraints.
- Assess alternative policies, plans and programmes.
- Identify environmental substitutes and / or trade-offs.

As indicated elsewhere (Chapter 3), this is basically the same as an SBPP/MCDA process outline. What is not specified in the SEA literature available to date, is the means by which alternatives will be assessed, nor how environmental trade-offs will be established or identified. One of the potential problems to the proposed SEA approach, as listed in CSIR (1999), is the difficulty of prioritising issues to be addressed and trade-offs to be made. These are exactly the areas in which MCDA tools can provide assistance.

5.1.5 RRA, PRA[5]

MCDA, OHP and SEA all claim (or aim) to facilitate stakeholder input into the decision-making process. In order for these to be able to include an adequate range of societal values, a skilful facilitator and appropriate methods of eliciting these are needed. The techniques used in rapid and participatory rural assessments (RRA and PRA) such as needs assessment, resource mapping etc. may be useful in this regard. Following a full PRA (Chamber, 1994) would allow stakeholder communities to define problems for themselves through the identification of issues of concern, the state of the resource and potential actions for remediation. Without this, the problem structuring stage could be effectively 'hijacked' by the managing authority, consultants, and high profile stakeholders. Decisions taken then run the risk of being irrelevant to communities, or of creating hostility and resistance. However, the need for delivery and action would need to be balanced against the need for in-depth and extensive, and therefore time-consuming, PRAs. There will be a need for 'fast-track' decision-making using MCDA, OHP or other techniques which can include stakeholder input in various forms, while more extensive PRA type exercises are underway.

5.2 Methods and tools used during evaluation

5.2.1 MCDA/SMART

The reader is referred to, in particular, Chapter 2 and Chapter 3.

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[5] Rapid Rural Appraisal, Participatory Rural Appraisal

5.2.2 Monetary valuation of ecosystem services

The process of incorporating the 'economic importance' of water resources is being developed as part of the implementation of the NWA. A project funded by the WRC and carried out by Mander, Quinn (University of Natal) and Turpie (UCT), intends to 'place a value on the quantity and quality of services provided by aquatic ecosystems, as well as identifying who the beneficiaries of these services are' (DWAF, 1999b). Factors which will be considered include, amongst others, regulation of the atmosphere, climate, water and sediment supply, nutrients, and soil erosion, the role in food and raw material production, and in recreational use (the overlap with 'social importance' criteria will have to be dealt with). The project proposes comparing the value of conserving rivers with the value of alternative uses (scenarios in our terminology)and thus the approach is similar to SBPP/MCDA as discussed in Chapter 3.

The emphasis of the economic importance evaluation is on ecosystem services (and social importance) rather than on the economic comparison of alternative uses (e.g. irrigation), but financial implications will also be examined in separate studies. In this study, the distribution of benefits from ecosystem services will also be examined for different water user groups including industry forestry etc. and that the value to users should be estimated. The relationship between the service and the value to society will also be established (i.e. a value function as used in MCDA). They suggest that a number of scenarios could be developed to illustrate the trade-offs that may occur between water quantity and quality, ecosystem services, and changes in demand for services and water abstraction, and the implications of selecting specific EMCs. This would be similar to the SBPP/MCDA approach and the suggestions made in Section 4.2. Mander and Quinn suggest that the success of the approach would depend on the extent to which monetary valuations could be attached to ecosystem services. Within an MCDA framework, monetisation is not necessary, and consequently perhaps 'success' more likely.

5.2.3 Risk and risk assessment

The documentation laying out the various measures for implementation of the NWA promote setting limits and objectives 'on the basis of acceptable risk' (DWAF, 1999b). Objectives should reflect the 'understanding and acceptance of a particular level of risk of exceedance and 'causing irreversible damage'. The acceptable risk level relates to 'the value or importance we place' on a resource. It is suggested that a 'risk-based approach provides a nationally consistent basis for deciding on the acceptability of impacts' and that the concept of 'levels of risk, and levels of protection, which are nationally applicable, rather than the numerical objectives themselves' (DWAF, 1999b). Thus, for 'water resources which are important, sensitive, or of high value, little or no risk would be acceptable, and they would be assigned a high protection class', while for others, the need for utilisation of water may be more important and a higher level of risk would be acceptable. The interest in the use of 'risk' is reflected in the project on ecological risk assessment in water resource management being undertaken by CSIR (1998-2000) and funded by WRC.

A rigorous 'risk based approach' using risk analysis and assessments of attitudes towards risk of various parties seems a complex approach to promote, but details are not available as to the actual methods being adopted within the project. A less 'rigorous' approach would be rather similar to the scoring and value function tools illustrated in this report (Chapter 3) (e.g. the shape of the value function can reflect attitudes to risk with respect to a particular criterion).

It is worth noting here that the word risk, as used in DWAF (1999b) incorporates at least two possible meanings: risk which arises because outcomes or consequences of decisions are unpredictable, and risk which arises because outcomes are undesirable.

5.2.4 Indices

Refer to Chapter 2, Chapter 3 and Chapter 9, and Stewart *et al.*, 1997.

5.2.5 Visualisation: ICIS, CRAM, CPLAN, IWR-PLAN[6]

Visualisation of the potential consequences of decisions is an important part of IWRM both for the specialist and non-specialist. The use of such software programmes as Arcview (ESRI, 1999), C-PLAN (1999), ICIS (CCWR, 1999), CRAM (Chapman *et al.* 1995) or IWR-Plan (IWR, 1999) could be useful in facilitating this process while also providing a platform for managing data, hydrological programs, and integrating these with GIS. Use of these systems also means that, where the relevant expertise or analysts are geographically dispersed, advantage can be taken of networks to integrate results of models etc. CPLAN, IWR and Arcview also contain tools for analysis of information. CPLAN calculates 'minimum sets' of reserves to achieve pre-determined goals, while IWR (an MCDA based tool) allows one to determine trade-offs between different criteria.

5.3 Summary: Appropriate integration of available methods

The test of any decision-aiding technique is 'whether the choice is clearer after the analysis than before', whether it 'reveal(s) what people want and why they want it' (Green, 1995). Depending on the context, type and level of decision only some of these forms of decision support would be necessary, relevant or help in revealing 'what people want'. The techniques mentioned have different strengths and aims and could be integrated in various ways depending on the context, as well as the time, data and personnel available.

5.3.1 Problem structuring and framework

SBPP/MCDA, OHP, CBA and SEA could all provide overall frameworks within which other activities and decision stages could occur, and the choice would depend on the context. These frameworks all allow for input from stakeholders and inclusion of different types of information form different sources. Only SBPP/MCDA and OHP are referred to below, as SEA is considered to be essentially the same as MCDA. The outcome of the structuring phase within the SBPP/MCDA context is the definition of objectives, criteria and value trees, while the outcome from OHP would be the OH itself (similar to a value tree), defined goals, and actions to achieve goals. CBA offers useful concepts for consideration within a decision-problem. These include the different 'use values' and the inclusion of the effect of time (in terms of NPV).

5.3.2 Stakeholder participation and inclusion of values

Stakeholder participation would occur at various levels depending on the context, and consequently different 'tools' would be appropriate:

Extensive and deep participation	PRA type approaches may be essential here when time permits. These may be structured so that information, preferences, values can be assimilated directly into the SBPP/MCDA/OHP.
Extensive and shallow participation	Public meetings can serve to identify criteria and alternatives for inclusion in SBPP/MCDA/OHP.

[6] Integrated Catchment Information System, Catchment Resource Assessment Model, Conservation Planning, Integrated Water Resources Planning

Select and deep participation	This would occur where representatives of stakeholder groups become part of one or several working committees within and SBPP/MCDA/OHP process
Specialist representatives	Often various specialists and government officials (e.g. from DWAF, DEAT) would represent their own, official and stakeholder views within SBPP/MCDA/OHP.

5.3.3 Provision of other information

Technical information would be provided within SBPP/MCDA/OHP by the results of EIAs (which could be performed using MCDA tools for ease of assimilation), instream flow requirement exercises (BBM, DRIFT), hydrological modelling, ecological, social, economic, engineering studies, spatial (GIS) analyses etc.

MCDA and OHP could include these types of input 'naturally' within a coherent framework, while CBA would need to convert to monetary terms. CBA and monetary evaluation tools would also provide technical information for inclusion within SBPP/MCDA/OHP.

5.3.4 Visualisation of consequences

As mentioned, ICIS, Arcview, CPLAN, etc. offer valuable ways of visualising alternatives.

5.3.5 Evaluation of alternatives, determination of trade-offs.

Once consequences have been examined in various ways, MCDA offers the only real support in this area beyond ad hoc analyses. Naturally a CBA also evaluates alternatives and trade-offs, but not (usually) in a transparent and accessible form.

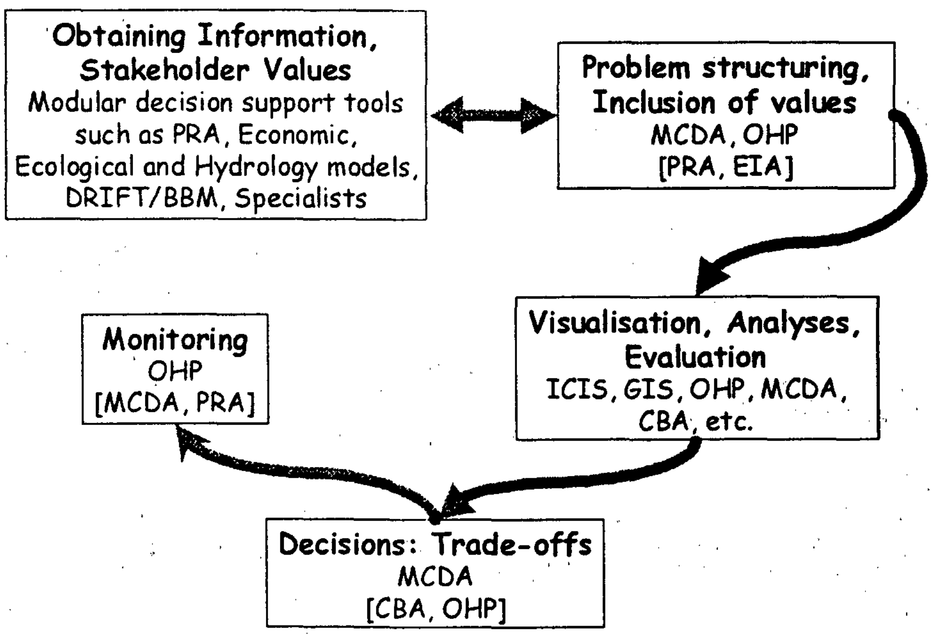


Figure 5.1. Decision support methods and their roles for IWRM. Where it is not clear if a method provides support in a particular stage, it is included in square brackets.

Chapter 6. Introduction to, and principles arising from case studies

The authors have been involved in several applications of MCDA during the course of this project, and some of these are reported in the following chapters. They fall into two categories: land-use/ catchment planning, and classification and prioritisation. Three of these (Sand River catchment planning, Maclear district and Baviaanskloof Wilderness Area land-use planning) illustrate ways in which SBPP/MCDA processes and tools can be used, while the estuary classification illustrates the use of MCDA in forming indices. Of all of these, the Sand River case study most closely resembles the types of problems to which we envisaged SBPP/MCDA being applied. It also most clearly points to the potential future role for SBPP/MCDA within catchment planning, perhaps as means by which CMAs can develop CMSs. Below we outline for each of the projects where relevant:

- the overall objective,
- the client(s),
- the outputs,
- and the use made of the outputs.

The chapters that follow are (more or less) the project reports as written for the client, and have followed slightly different formats in each case.

Section 6.3 summarises the 'lessons learnt' from these and other studies

6.1 Land-use or catchment planning – analysis of scenarios

6.1.1 Sand River catchment planning

The Sand River catchment project was run as a pilot project to investigate approaches to catchment planning within an integrated catchment management framework (the shift in policy emphasis to 'integrated water resource management had not yet been made). The overall project was commissioned by DWAF and the Department of Agriculture, undertaken by AWARD (Association for Water and Rural Development) and funded by Sabie-Sand Game Reserve. AWARD invited AJ to run the decision-aid part of the project. This decision-aid concentrated on the land-use and associated water-use implications, while the broader project also considered bulk-supply issues, water conservation strategies, catchment management agency structuring, education and training and etc. The decision-aid consisted of:

- an overall SBPP/MCDA framework within which four workshops were run with the project team of specialist who broadly represented ecological, social and economic issues in the catchment.
- a SMART approach to scenario evaluation (thermometer scales swing weights)
- the development of a database for the analyses.

The output consisted of a report which formed a chapter of the overall Sand River project write up (Pollard *et al.*, 1998). This output was used to make overall recommendations regarding land-use in the catchment. These recommendations are being carried through into Phase II of the Sand River project. The SBPP/MCDA work was reported (in very abbreviated form) at the South African Society of Aquatic Sciences conference (June 1999) and at the Integrate Management of River Ecosystems conference (August 1999). Similarities and differences between this and the Maclear land-use example are shown in Table 6.1.

6.1.2 Maclear forestry and land-use

This project was reported in the previous WRC report (Stewart *et al.*, 1997) before its completion, and is included here for completeness. Prof. van Hensbergen of the University of Stellenbosch invited TJS and AJ to run an SBPP/MCDA exercise to look for 'appropriate' levels of afforestation in the Maclear magisterial district. There was no direct client, although the forestry company and DWAF could be considered to be clients. The decision-aid consisted of:

- an overall SBPP/MCDA framework, within which four workshops were held with representatives of various interests
- a SMART approach to scenario evaluation (thermometer scales, swing weights)
- the development of a database for the analyses

The output consisted of a report which was sent to the participants. The project was reported in brief at the South African Statistical Association conference (November 1997). The general approach was also reported to a meeting of the Forestry Review Panel in the Eastern Cape (1997) as a possible strategic level planning tool, within which licensing decisions could be made. The recommendations were not taken further. An EIA was commissioned to decide about expansion of forestry onto land with high conservation value, and SEA is in the process of being adopted for strategic level forestry planning and for decision aid for SFRA licensing. Similarities and differences between this and the Sand River project are shown in Table 6.1.

Table 6.1. Summary of similarities and difference between the Sand and Maclear case-studies

	Forestry & Land use	Sand Catchment Management Plan
Key question / Objective	Appropriate levels of afforestation	Integrated catchment management plan
Approach	Simple SBPP, Cog map (AJ only), SMART	Simple SBPP, Cog map (AJ only), SMART
Time frame and workshops	18 months. Four workshops with group	3 months. 5 workshops with group
Alternatives?	Development and evaluation of scenarios	Development and evaluation of scenarios
	Status quo	Status quo
	4 levels of forestry expansion	3 zones
	+environmental constraints	possible levels of expansion (shrinkage) of
	+primary processing	irrigation, forestry, conservation in each zone
	= nine scenarios	Zone A = 8, Zone B = 3, Zone C = 4 scenarios
Criteria	As identified by group	As identified by group
	Economic	Economic
	Social	Social
	Ecological	Ecological
Source of information	Ecology- previous study, participation of experts	Ecology - previous studies, participation of experts
	Hydrology - previous study, participation of experts	Hydrology - some modelling - not calibrated to current
	Economics - collation, analysis by AJ	Economics - part of project - not calibrated to current
	Social - input of group	Social - input of relevant experts & group
Scoring approach	0-100 thermometer scale	0-100 thermometer scale
	Weights	Weights
	Additive (independence tested?)	Additive (independence not really tested)
Computer packages	**Excel**	**Excel**
	All farms linked to relevant information. Automatic update of information and some scores with change in scenarios	Each zone with number of hectares. Automatic updating of certain scores with changes in hectares
	For project write up, graphics, sensitivity etc.	For project write up, graphics, sensitivity etc.
	Scores, weights, aggregation	Scores, weights, aggregation
	VISA	**VISA**
	Extensive use during workshops	Limited use (AJ only)
Problems / Issues	Disagreement about employment numbers	Economic and hydrological information
	Disagreement about multipliers	Technology (couldn't use computer in workshops)
	Changing membership of group	No final "wrap-up" with group - benefit not clear to them?
	Benefits of approach only clear at last workshop?	Write-up not best format
	Write-up not best format	Trade-offs – monetary values. Of interest but not possible
	Trade-offs - monetary values (of most interest to many)	to present to group

6.1.3 Baviaanskloof land-use options

The Baviaanskloof project was a result of a proposal by Eastern Cape Nature Conservation to expand the Baviaanskloof Wilderness Area (BWA) into privately owned agricultural land surrounded on three sides by the BWA. The proponents were interested in an evaluation of the proposal from the point of view of direct, indirect and non-use values, and in a broader framework for comparing options. Brad Smith (University of Cape Town) was invited to do this work and asked AJ to apply an SBPP/MCDA approach to complement this. The work was funded by Vodacom and Telkom, and the client was the BWA conservation manager.

The decision-aid approach consisted of:

- A broad SBPP/MCDA framework within which a public meeting and a workshop were held.
- An ordinal ranking of scenarios (project stopped before more in depth evaluations could take place)
- The development of a database.

The product of the project was a report which was sent to the main participants giving a preliminary ranking of alternatives.

The work will not be taken further, but a WWF funded project will assess the original proposal in some depth from a conservation point of view (mainly as a means to obtain funding for implementation and land-acquisition).

6.2 Classification of estuaries into management classes and prioritisation

This project formed part of DWAF's implementation of the NWA. Dr Jane Turpie (University of Cape Town) was contracted to do the classification of estuaries for the intermediate reserve determination, and a preliminary prioritisation of estuaries for reserve determination. She invited AJ to participate in the exercise mainly in an advisory capacity. The decision-aid took the form of:

- Running one session of a workshop to define criteria (indices) to be used in the classification
- Advice regarding the formation of the indices and the meaning of weights
- Development of questionnaires to refine indicators and weights

These contributions were included in the report by Dr Turpie (2000) which forms part of the DWAF Resource Directed Measures initiative and is available at http://www-dwaf.pwv.gov.za/Documents/Policies/WRPP/.

6.3 General principles arising from case studies

There were three general areas in which the use of SBPP/MCDA provided support, and the issues discussed below should be seen in the context of these:

- Provision of facilitation (although the process and tools don't presuppose the use of a facilitator and/or analyst, this would appear to be one of the benefits)
- The provision of a framework and process (SBPP/MCDA)
- The provision of tools for use in various stages of a process (SBPP scenario building tools, MCDA scoring and weighting tools)

6.3.1 Role of Facilitator / Analyst

There are two main roles that an MCDA practitioner can play within natural resource management MCDA problems; that of facilitator/analyst as part of a team and that of advisor to a team. It has not always been evident in advance which role would be required, as there have seldom been 'terms of reference' drawn up for any particular case.

In some cases the facilitator / analyst role became an integral part of a project and the role extended beyond what the name might imply. This often meant the development and maintenance of a database with linkages of attribute values to scores and other relevant material, and sometimes included the sourcing and analysis of data. For example,

- For the Sand River catchment planning example, the facilitator/analyst analysed the preliminary results of hydrological modelling, accessed certain economic information, developed an extensive spreadsheet which automatically updated values with scenario changes an ran workshops .
- For the Maclear forestry case, the facilitator/analyst sourced economic data, canvassed local opinion on a small scale, developed an extensive spreadsheet which automatically updated values with scenario changes, set-up, organised and ran workshops.
- For the estuarine classification and prioritisation this meant several consultation meetings, attending and running a session of a workshop, and preparing questionnaires.

In all cases it seemed important that the analyst was *part* of the team, and willing and able to do 'extra' work. This may be more difficult in situations where formal 'terms of reference' are required (and adhered to!), as the process needs to be flexible. It seems that the closer the involvement the more mutual benefit. Benefits accrue to a team in terms of 'value-added' to a project (in particular, in understanding the links between issues), to the facilitator /analyst in terms of potential methodological development, and to the water management community in terms of skills transfer. However, people are still wary of 'taking on' MCDA and thus this level of involvement is still relatively unusual.

In addition, the facilitator/analyst needs to be able to maintain the required level of commitment, interest and enthusiasm from the project team during all phases of the MCDA process, and to ensure adequate understanding of all concepts at all stages.

The 'advisory role' should however not be discounted, as much can also be achieved in a short meeting or review in terms of contributing to specific aspects of projects. This advice is usually about scoring, weights and aggregation.

The facilitator needs to give the right sort of feedback to the group, that which is relevant and will promote understanding and reaching of consensus (e.g. trade-offs and WTP in some cases, but not in others). At the same time the facilitator/analyst should not shrink from revealing and exploring conflicts where necessary.

6.3.2 Role of workshops and other meetings

In the cases where there is comprehensive involvement of a facilitator/analyst this would usually occur in a series of workshops. This is one of the reasons that project leaders remain wary of MCDA as they perceive there to be a large and extra time commitment. This time commitment can be minimised by good co-ordination with the project leader, so that workshops occur as much as possible at the same time as the project team's own planning meetings. However, it is *essential* that sufficient workshops or time within workshops is given to the MCDA process. In particular, the initial and final workshops (or sessions of a single workshop) play a vital role.

The initial workshop (or session) must include a demonstration of a sufficiently relevant example of MCDA, including where relevant and possible the use of visual tools such as VISA. The remainder of the workshop would consist primarily of various problem structuring exercises (to identify criteria, scenario elements etc.). The facilitator/analyst needs to be kept informed about other activities within a project, so that this workshop could potentially be combined with other project planning meetings.

A final feedback or 'debriefing' workshop (or session) is essential. During this workshop the facilitator /analyst needs to concisely report back regarding sensitivity analyses, potential inconsistencies, revealed trade-offs, and overall conclusions. As much use as possible should be made of visual tools (e.g. VISA) and there should be as little as possible mathematical or arithmetical detail. The team needs to have time to digest this and to make possible adjustments. In the case of the Sand River project, there was no time available for such a meeting, and this had three consequences. The more important of these is that the team never saw the 'final outcome' and sensitivity analyses, except in the form of a written report, and were thus not in a position to appreciate the potential information and insights to be gleaned from these. Secondly, potential inconsistencies could not be identified and corrected. Thirdly, as a result, some of the team possibly did not appreciate the contribution of the MCDA process.

6.3.3 Role of technology

It is very useful to be able to use certain of the computer packages available for MCDA, but in a country such as South Africa, reliance on computer technology can be a drawback, and can alienate certain sectors. It is quite possible to complete the entire SBPP/MCDA process without using computers within workshops. For example, the Sand River project was completed without the use of computers during the workshops, as a demonstration of its feasibility. Use was made of an overhead projector and flipcharts, for visual representation of results etc. Scores were given on pieces of paper printed with a thermometer scale for each criterion (as has been mentioned, in relevant situations, scores and weights could also be given by allocating beans or stones to alternatives or criteria in PRA). Scores and weights were entered into VISA and an Excel spreadsheet and analysed after the session/workshop in question.

However, there were two main disadvantages of not having MCDA software available within the workshops:

- the process took longer, as information had to be entered and analysed between sessions/workshops.
- there was minimal opportunity for interactive feedback on scores and weights, as people could not immediately view (and consequently visualise) the implications of changes.

6.3.4 Time and groups

In situations where a group of 'specialists' representing different interests form the project team or a working committee for a problem such as the Sand River catchment planning, it is reasonable to expect that an MCDA process would require about 4 workshops or workshop sessions, at least for a first iteration. However, in situations where there is more public involvement, or initial resistance to a proposed project, or to a process, and/or initial conflict between different groups, more meetings would be needed. In these situations it would be preferable to meet with interest groups and run through several or all of the SBPP/MCDA stages with each group separately. The groups could be joined at various stages, and after the initial problem structuring, alternative generation, and criteria selection stages, it may be possible to do this even in situations where the initial conflict was fairly large.

As the SBPP/MCDA process will often involve more than one workshop, it is important that those involve commit themselves to attending all workshop where humanly possible. If representatives from a particular interest change from workshop to workshop, they will be a) less aware of the process, b) less able to meaningfully contribute, and c) less able to appreciate the usefulness of the process.

6.3.5 Theoretical issues

The contribution of MCDA is in providing theoretically justifiable tools. Although not always easy to do, the assumptions underlying these should be examined. In particular, checks should be made for the existence of non-linearity in the value functions and for preferential independence. When assessing weights between criteria groups, more accurate trade-offs can be made by comparing lower level criteria, and inferring the upper level weights (rather than comparing the groups directly). Care should also be taken in how questions regarding weights are phrased, as these are subject to various framing and other biases. Finally, the 'validity' of an analysis may be interpreted in terms of its rationality which can be divided into:

- Procedural rationality – is the method itself rational?
- Substantive rationality – are the results rational?

Clearly, the theory underlying MCDA implies that the procedure is rational and that the results should be rationally acceptable both of these being the basis of the approach. However, in the real world where not all assumptions can be guaranteed, perhaps the only way to 'validate' the approach is to highlight theoretical shortcomings and determine whether results were useful and/or counter-intuitive.

6.3.6 Estimating the usefulness of the MCDA process and tools

It is very difficult to determine the 'worth' of any MCDA contribution within a project. Firstly, there is no basis of comparison if another 'decision-aid' method has not previously been used. Secondly, at its best, an MCDA process would influence the structuring and thinking around a project in a very natural way so that one cannot say 'this was an MCDA insight and that was not'.

A questionnaire was sent to 10 people who had taken part in one of three case-studies (Maclear forestry, Sand catchment planning, and an environmental impact assessment) in order to assess their feelings about MCDA and its utility. Of these, nine responded although not to all questions. In general (8/9) found the process useful, particularly in terms of the holistic integration of different views or factors, and (in so doing) gaining an insight into the relative importance of these. The majority also found the various tools relatively easy to understand (thermometer scales, swing weights, sensitivity analyses). However, many found the actual giving of scores and weights difficult. A few comments were made regarding lack of understanding (e.g. of sensitivity analyses), the difficulty of transferring understanding to decision-makers, or the practicality of the methods (see Figure 6.1 and Table 6.2).

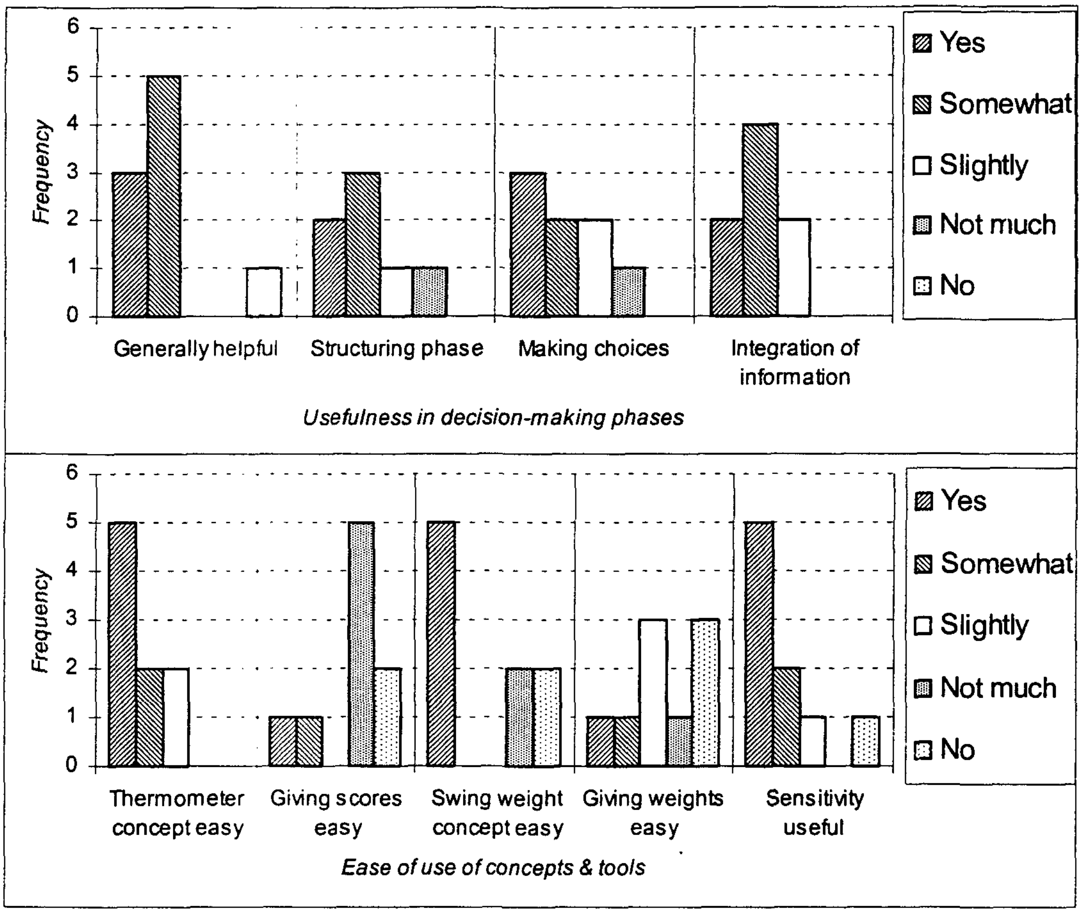


Figure 6.1 Responses to questionnaire.

Table 6.2. Comments arising from the questionnaire. R = respondent code.

Question	R	Comments
Was the sensitivity analysis useful?	7	Can't comment, it was difficult to understand.
Were results of MCDA used/implemented?	1	Yes, in the Sand River project phase 2.
	2	Yes, the results were used to propose potential (best) land and water use practices in the Sand sub-catchment. This is now being implemented.
	3	Yes, integration of different aspects of the study. Also to calibrate (normalise) different issues.
	7	Yes (some), provided support for the reduction in forestry in the catchment, particularly in terms of a 'quantitative' analysis of the situation. General recommendations accepted.
	4	No, full project not completed.
What general insights were gained?	2	Helped to prioritise the relative importance of a vast range of factors (in relation to each other)
	3	Relative importance of issues
	4	Go / no go decisions on projects are still made on the basis of single key issues which override all others. So MCDA works well on creating a hierarchy of the minor solvable problems
	6	An additional tool
	7	Insights in terms of decision-making support systems
	8	Too early to say
If result were not used, why?	3	Lack of understanding of concepts.
	5	Didn't specifically use results in report but they may have provided insights that influenced it.
	7	In terms of specifics, it would be difficult to get buy-in to decisions from government departments. Not sure we could explain sufficiently to get them to 'understand'.
	8	Method not yet fully practical.
	9	Am involved with usual impact assessment which is a relatively subjective issue. I feel that the MCA results did not fit with my own analysis.
Other comments	2	A good way to incorporate different data from different disciplines to provide a holistic picture.
	3	Publish, present and communicate the approach.
	5	Useful in exposure to a different way of looking at things
	8	Helped in understanding of diverse views
	8	Feeling that method may still be too theoretical / academic.
	9	If we spent some more time refining the system, 'emotional' and subjective issues will be brought into the MCDA in a meaningful manner

Chapter 7. Development and analysis of land-use scenarios for the Sand River Catchment

A team of specialists (AWARD) were tasked with the development of an integrated catchment management plan with associated land care and water conservation plans for the Sand River Catchment (SRC), Mpumalanga. The time frame of the project was approximately three months, during which time the project team had to collate all available information for the catchment, as well as do further research where necessary and possible (e.g. hydrology, economics and water-use of irrigation schemes). In parallel with this, the team participated in four 'decision conference' workshops in order to complete the SBPP/MCDA work described here, which formed part of the broader study. For a full report of the broader project and the work described here see Pollard *et al.* (1998). The whole study was done under extreme time constraints - any inaccuracies resulting are repeated here.

The SRC (1910km^2) is a subcatchment of the Sabie catchment and contributes about 20% of the Sabie's mean annual runoff. There is high inter-annual and spatial variation of rainfall: the escarpment in the west, has an average annual rainfall of about 2000 mm, while the eastern side of the catchment has a about 550 mm. Three hydrological studies for the catchment under present afforestation levels, arrived at widely different estimates of mean annual runoff ranging from 96 to 215 Mm^3. The upper catchment has some 5000 ha of forestry plantations, the lower catchment is commercial and state nature conservation, while the middle catchment is where most human activity occurs, including some government irrigation schemes, grazing, dryland crop farming, small garden plots, and small urban areas. The 1998 population was approximately 337 000, amongst whom there was 40-80% unemployment (population and employment figures being as widely varied as those of runoff).

The SRC was chosen for this project as it was recognised that the natural resources of the catchment were degraded and depleted due to inappropriate land and water-use, precipitating further socio-economic problems which, in turn, exacerbated the environmental problems. The perceived water resource and land-use management problems in the catchment were, amongst others, water-use by exotic plantations in the upper catchment, water-use by the irrigation schemes, lack of payment for water services, lack of bulk supply to some areas, shortages of water in the lower catchment, inappropriate land-use (e.g. irrigation schemes in a water-poor environment) and bad land-use practice (e.g. plantations in riparian zones and on steep slopes).

7.1 Methods

As part of the development of an integrated catchment management plan, use was made of the SBPP/MCDA framework and tools as described in Chapter 3 to develop, evaluate and help to choose between hypothetical land and implied water use scenarios for the SRC. The SBPP/MCDA stages occurred in four workshops with the project team who represented various points of view (viz. ecological, social, economic), while AJ facilitated the workshops and completed intermediate MCDA work and other analyses between each workshop.

The workshops were run and scores and weights were derived during them without the use of computers and decision support software. Various software was used for intermediate analyses including MSExcel (Microsoft, 1995), VISA, and Decision Explorer and results reported back to the project team using an overhead projector and flipcharts. Only Excel was essential to this process.

The development of the catchment scenarios is described in the following section. A description of the selection of criteria, formation of the 'value tree', and evaluation of scenarios follows. The derivation of the weights used in the summation of scores is then described.

7.1.1 Development of catchment land-use scenarios

Scenarios were formed by asking the team directly about 'scenario elements' (Chapter 3) and by using their knowledge and available information to develop a manageable set of realistic scenarios for which it was hoped that economic and hydrological consequences could be modelled within the time-frame of the project. The catchment was divided into three management zones based on areas of similar present land-use patterns, climatology, topography, and consequent demographic patterns (Table 7.1 and Figure 7.1). Combinations of different levels of different land-uses were used to form catchment scenarios within these zones. In other words, the land-use levels became the 'scenario elements'. Although elements other than land-use could have been included, land-use was the driving force behind all other economic activity in the catchment (there being no heavy or service industry apart from that associated with tourism). Land-use was also a direct cause of most of the environmental problems in the catchment. The eight land-uses in the catchment were: conservation, rangelands, afforestation, residential, residential with garden plots, permanent irrigation, annual irrigation and dryland agriculture. Note that where reference is made to either conservation or rangelands, the implied land-cover is indigenous grass, bush and woodland in both cases, with some coppiced bushland and overgrazed grassland occurring in the rangelands.

Land-use scenarios were developed and evaluated separately in each of the three zones: eight in Zone A, three in Zone B, and four in Zone C (Table 7.1). The number of hectares of each land-use in the scenarios was based on the realistic potential for certain land-uses in the different zones. For example, there was some potential for more irrigation in Zones A (about 1890 ha) and B (about 3250 ha), based on slopes and soils, and there was some potential for increased afforestation in Zone B (about 7300 ha), based on slope, soils and rainfall.

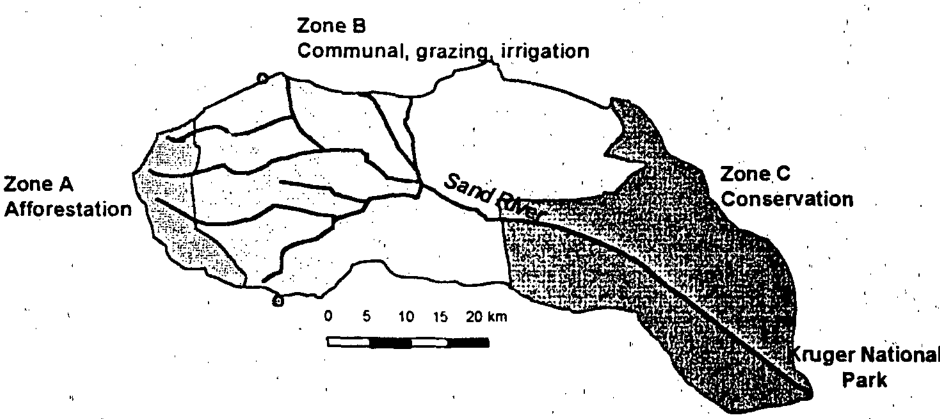


Figure 7.1. Zones used for the development of alternative scenarios within the Sand River catchment.

Zone A

Zone A was approximately 11582 ha, 43% of which is taken up by commercial plantation forestry with exotic species (mainly pine). The zone was delimited by the current extent of afforestation (apart from a small section in Zone B) on the eastern boundary, and the catchment limits on the western boundary. The rest of this zone was a combination of bushland, indigenous forest, woodland and grassland, about 20% of which was used for grazing, the remainder being inaccessible. This land-use pattern was modelled as **Scenario 1** - the status quo - enabling the group to assess whether keeping the present level of afforestation had benefits which outweighed its environmental impacts.

The development of other scenarios in this zone was predicated on the fact that an estimated 25% of the afforested area violated present forestry practice code as it was on steep slopes, riparian and wetland areas and therefore would have to be cleared. This was therefore a minimum requirement and modelled as **Scenario 8.**

The remaining scenarios removed 50% of forestry (2497 ha), and replaced half of this (1248.5 ha) with another land-use. The remaining 1248.5 ha would be cleared, remain undeveloped and under forestry management (except Scenario 7) as most other land-uses would also be unsuitable on steep slopes, riparian and wetland areas. The expense of rehabilitating previously afforested soils was not addressed.

In **Scenario 2**, 50 % of the presently afforested area would be cleared, and half of this (1248.5 ha) would be replaced with irrigated permanent crops (trees). **Scenario 3** would replace the same area with dryland cultivation, **Scenario 4** with rangelands, **Scenario 5** with irrigated annual crops, and **Scenario 6** with residential and garden plots. For **Scenario 7**, the entire 2497 ha was assumed to be used for conservation: in this case "community conservation" (Table 7.1).

Zone B

Most of the SRC fell into Zone B (109370 ha) which is delimited by the forestry area in the west and the commercial conservation area in the east. This was the zone in which the majority of people live and work, with land-uses including government irrigation schemes, dryland agriculture, grazing (on natural land-cover), residential areas with garden plots used for small-scale vegetable growing, and more dense residential areas. Potential for expansion of irrigation, afforestation and conservation was used as a basis for the scenarios. Three scenarios were formulated, all of which took into account the likely increase in population to the year 2010 and therefore the increased extent of residential areas. These expansions all occurred at the "expense" of rangelands.

In **Scenario 2** irrigation and afforestation were expanded to their maximum potential levels, while also expanding conservation into the zone based on a community conservation model (Table 7.1). **Scenario 3** was similar but considered more realistic, as no increase in afforestation was proposed, and smaller increases in irrigation and conservation were proposed than for Scenario 2. **Scenario 4** was simply a projection of the status quo to 2010, taking into account the increase in population and the concomitant increase in residential areas. Another scenario, **Scenario 1**, which was the status quo, but for the 1998 population rather than that of 2010 was not evaluated further, but included as a reference point.

Note that Zone B was the only area in which population growth was incorporated into the scenarios through the effect on housing area required and water demand. It was felt that, considering the results of initial analyses for Zones A and C, there should preferably not be a shift of population into these areas, and therefore any increase in population would have to be accommodated in Zone B. In order to calculate the expansion of residential areas, the current population figure of 336 638 was projected, at a growth rate of 2.4%, to a population of 447 469 in the year 2010. The current population divided by the current residential area (17 859 ha) gave a density of 18.9 people per hectare. At the same density the projected population for 2010 would require 23 739 ha. Split in the same proportions as at present between dense and sparse residential (0.15:0.85) gave areas of 3 656 ha and 20 083 ha respectively.

Zone C

Zone C (70 039 ha) consisted of private and state game reserves (i.e. 'commercial conservation'), and was defined by the present western borders of the game reserves and the catchment limits in the east.

Scenario 1 was the status quo: commercial conservation on 69 487 ha. For **Scenario 2**, 20 % of this land was converted to rangeland with land-cover as specified earlier. **Scenario 3** was the same as Scenario 1, except that one of the game reserves (Manyeleti, 3 622 ha) came under community management with no natural resource harvesting, while **Scenario 4** was the same as Scenario 3, but allowed harvesting on 20 % (13 173 ha) of the current commercial conservation area (Table 7.1).

Table 7.1. Land-use scenarios for the Sand River Catchment. Measurements in hectares.
For = Forestry, PI = permanent irrigation, AI = annual irrigation, DA = dryland agriculture, RL = rangelands, R&GP = residential and garden plots, CmCon = Commercial conservation model, CCon = Community conservation model, NRH = natural resource harvesting, Man = Manyeleti.

a: Zone A scenarios.

Total area (excl water) – 11581.7 ha	Forestry	Unused*	Permanent irrigation	Annual irrigation	Dryland agric	Grazing	Community cons^n^, NRH	Residential + garden
Scenario1-SQ	4994	5270	0	0	0	1318	0	0
Sc2-For↓50%,25%→PI	2497	6519	1249	0	0	1318	0	0
Sc3-For↓50%,25%→DA	2497	6519	0	0	1249	1318	0	0
Sc4-For↓50%,25%→RL	2497	6519	0	0	0	2566	0	0
Sc5-For↓50%,25%→AI	2497	6519	0	1249	0	1318	0	0
Sc6-For↓50%,25%→R&GP	2497	6519	0	0	0	1318	0	1249
Sc7-For↓50%,50%→CCon	2497	5270	0	0	0	1318	2497	0
Sc8-For↓25%	3746	6519	0	0	0	1318	0	0

* Newly cleared riparian areas, wetlands and steep slopes (1249 ha) would be forestry managed.

b. Zone B scenarios.

Total area – 108725	Forestry	Permanent irrigation	Annual irrigation	Dryland agric	Grazing	Residential and garden	Dense residential	Community cons^n^, NRH
Sc2maxpot	7307	989	4843	10275	53382	20083	3656	8190
Sc3realistic	0	724	3545	10275	66347	20083	3656	4095
Sc4sqproj	0	438	2145	7743	74659	20083	3656	0
Sc1SQ	346	438	2145	7743	80194	15109	2750	0

c. Zone C scenarios.

Total area - 69770	Grazing	Commercial conservation	Dense residential	Community conservation	NRH
Sc1-StatusQuo	0	69487	283	0	0
Sc2-↓CmCon,↑RL	13897	55589	283	0	0
Sc3-Man→Ccon	0	65865	283	3622	0
Sc4-Man→CCon, NRH in 20% CmCon	0	65865	283	3622	13173

7.1.2 Criteria and value tree formation

The terms of reference of the project team specified as the overall objective the rehabilitation of the SRC through the principles of 'integrated catchment management' and 'landcare'. In turn, promoting rehabilitation and sustainability would be achieved through economic growth, equitable access to water, and sustainable and appropriate land- and water-use. Some of the criteria for evaluation of the scenarios developed naturally through the further refinement of these objectives while others were obtained in 'brainstorming sessions' during the workshops. The objectives and criteria were organised into a value tree (iteratively), and the scenarios evaluated on the basis of 18 criteria (Figure 7.2).

The criteria contributing to the goal of <u>economic growth</u> (EG) were: the operating margin or profit resulting from the different scenarios (the total profit to the catchment zone accruing from all land-uses in the scenario), the total income earned in formal occupations and informally through harvesting of secondary and natural resources. Other suggested criteria were: contribution to gross geographic product, ability to attract investment capital etc., but these were rejected as it was felt that available data would not support their determination, and also that other criteria already partially measured these.

Although employment is conventionally considered an economic criterion, the two employment criteria (total number of informal and formal jobs) were included in the group of criteria contributing to the goal of social upliftment and equity (SE) as employment was the primary means of achieving this higher level goal. The criterion 'water equity' was intended to be a measure of how many people could be supplied with different levels of water supply, as access and distribution were patchy and skewed. Land equity was a rather 'fuzzy' criterion. It related to land tenure systems, access to and use of resources associated with different land-uses. For example, most of the land under natural vegetation is communal rangeland. Access to these means that pasture and natural resources for harvesting are available. The criterion 'greenspace and aesthetics' related to how much uncultivated land remained in the catchment, 'river access' to whether, under new land-use arrangements, residents would have access to the river for drinking, washing, social, ritual and gardening use. The 'social value of harvesting secondary and natural resources' related to both the cultural aspects associated with harvesting and the fact that being able to harvest meant that those with no other income or resources gained a sense of worth through relative self-sufficiency from this source. The social criteria relating to health, crime and infrastructure were regarded as fairly standard criteria to use, but in fact were not directly affected by the scenarios being assessed. Indirect effects would mainly be due to changes in employment, remuneration and equity, which were already addressed elsewhere. However, the social specialists felt that these criteria should be retained in the middle catchment, rather than give the impression that these issues were not considered. Double-counting could then be counteracted by giving them low weights.

Criteria which contributed to the goal of rehabilitation and sustainability (RS) were grouped into two categories: those relating to terrestrial ecology and those relating to aquatic ecology. Effects on terrestrial ecology could be assessed in terms of terrestrial species richness and habitat diversity, soil erosion, spread of alien invasive species which are all directly affected by land-use. Aquatic habitat diversity, water quality and the catchment water yield (i.e. effects on runoff) are directly and indirectly affected by land-use. Clearly 'sustainability' is the overall objective of an integrated catchment management plan. The inclusion of the term in this group indicates that the sustainability of resource *use* is mainly measured in terms of impacts on ecology.

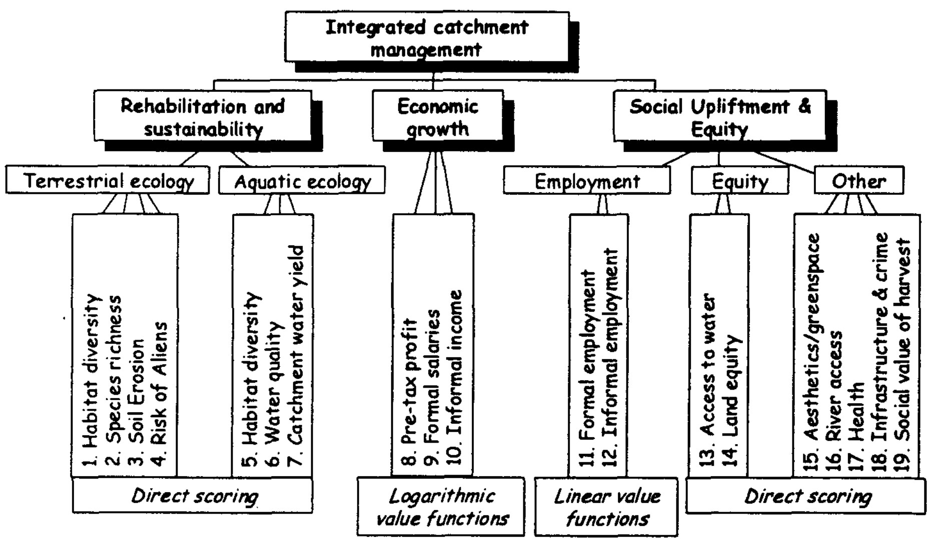


Figure 7.2. Value tree structure, criteria used and their associated scales. Criteria 7 and 13 could be quantitative once appropriate hydrological information were available.

7.1.3 Consequences and evaluation of scenarios

The consequences of the scenarios were therefore examined in terms the criteria 1 to 18 in the value tree (Figure 7.2). The quantitative or qualitative evaluations were based either on data arising from this project and previous studies or on the opinion of the relevant specialist on the project team based on their previous experience and work in the area. Therefore, both direct judgemental scoring and value functions were used (Chapter 3).

Thermometer scales or direct scoring by the relevant specialist on a 0-100 scale were used for 13 criteria i (Figure 7.2). The score, $v_i(a)$, related indirectly to one or more unmeasured attributes, z_k, or consequences of the scenario a. In other words, $v_i(a) = f(z_1, z_2, \ldots, z_k)$, where the z_k included the hectares of different land-use, but may have included other issues. Although for criteria such as species richness, some comparative, quantitative assessments were available, the use of a value function relationship was not felt to be necessary. In the absence of final hydrological models for the scenarios, specialist judgement was used for the criteria relating to aquatic habitats, catchment water yield and water equity. Value functions might have been used if hydrological model results were available.

Linear value functions (v_i) translated data ($x_i(a)$) into 'value' on a 0-100 scale for two criteria and non-linear value functions translated data to 'value' on a 0-100 scale for three criteria (Figure 7.3). In other words, these five criteria were directly related to a measured attribute. The relationship between numbers employed and value was regarded as being linear: with the high unemployment levels in the catchment the flattening off of a logarithmic curve was inappropriate (Figure 7.3). Little time could be spent examining the shape of the non-linear value function criteria, other than to establish that they were generally logarithmic or steeper, and so a logarithmic relationship was used for convenience[7].

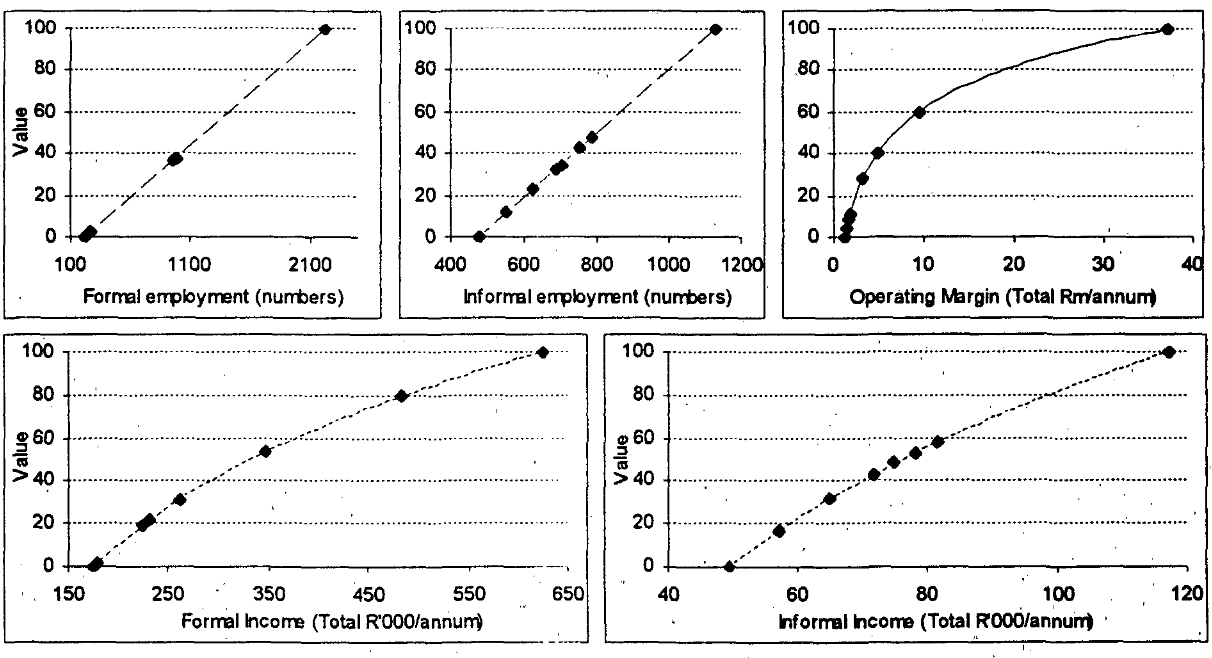


Figure 7.3. Value functions for the quantitative criteria.

[7] A financial analysis of earnings from harvesting secondary and natural resources was adjusted to include the non-cash costs of harvesting and transportation. The resulting incomes from harvesting were considered conservative as the costs included factors such as the cost of transportation to urban centres (whereas indications are that most produce is sold locally). Only economic implications from primary land-uses were assessed and no multiplier effects were included. It is likely that multiplier effects for any of the land-uses proposed here would be similar, all being agriculturally based, and therefore involving mainly transportation and packaging. Multipliers from tourism could be higher if more services were based outside conservation areas.

7.1.4 Aggregation of scores for each zone

For each zone and using a range of weights to assess sensitivity, the scenario scores were aggregated using a weighted summation (7.1 and Chapter 3), giving an overall value for each scenario *V(a)*:

$$V(a)=\sum_{i=1}^{n} w_i v_i(a) \quad \text{or} \quad V(a)=\sum_{i=1}^{n} w_i v_i(z_i(a)) \tag{7.1}$$

where for criterion i, w_i is the weight, $v_i(a)$ represent directly assessed scores, and $v_i(z_i(a))$ those derived from value functions. A range of values for the weights were used to assess sensitivity of the model.

The scores could be aggregated to various levels up the value tree to guide future decision makers. Thus, the scores for the four criteria in the group 'terrestrial ecology' were summed to give a 'terrestrial ecology' score, the terrestrial and aquatic ecology scores were summed to give a 'rehabilitation and sustainability' score, and 'rehabilitation and sustainability', 'economic growth' and 'social upliftment and equity' scores were added to give overall scores for the scenarios relative to each other. Preferred scenarios or 'directions of preference' could then be identified overall, or from different points of view, for different zones in the catchment. Overall performance could thus be compared with performance on any of the 18 criteria or with performance on the three grouping criteria. So for example, a scenario may have performed well overall but very badly from the point of view of 'formal employment' or from the aggregate SE point of view. This can either help to highlight potential new scenarios, or indicate that a scenario which performed slightly less well overall was preferable because it did not score very badly for any one criterion.

7.1.5 Criteria weights

The use of weighted addition presupposes that an improvement in one criterion compensates for a decrease in another criterion. The scales and weights used determine this trade-off and the use of a swing weight approach will, at least roughly, provide the correct trade-off.

To find weights or scaling constants for the criteria *within* the three criteria groups; RS, EG and SE, the team was divided into three groups, with the expertise of each group corresponding to each of these issues. The weights were given by the relevant members of the team using the swing weighting approach (Chapter 3). The three groups evaluating within criterion group weights, independently developed different strategies for assessing weights:

- The *social group's* strategy was to develop a trade-off between the number of hectares of cattle grazing land, used as a proxy for land-equity, and the number of people formally employed.
- The *ecological group's* strategy was to decide which 'rehabilitation activity' they would choose if they could spend a million dollars on just one activity.
- In comparing formal and informal *employment* the whole group decided that they should be treated as equal, but that sensitivity analyses should assess the impact of weighting one formal job as worth two informal jobs or vice versa, as arguments were given to support both of these ideas.[8]

The weights *between* the three criteria groups, RS, EG and SE were determined by the group as a whole. In practice, while appropriate elicitation of weights at the lowest (criterion) level may be possible, at higher levels, determining the swing weights between criterion groups is probably less reliable. To determine appropriate weights for the criterion groups, two approaches may be adopted in workshops, both of which use the swing weighting idea. In the first approach, the criterion groups can be directly compared, in which case, it is likely that the 'intrinsic importance' of the group or a criterion within the group will determine the weights. In the second approach, lower level criteria can be directly compared across all groups and a criterion group weight inferred. The latter approach is more likely to

[8] This was done, but, as it made little difference, the results not reported here.

reflect actual trade-offs between criteria and criteria groups. For various reasons, the former approach was used in this study. As the whole group was involved in previous discussions it is possible that a common frame of reference was achieved. In general the rank order of these weights was not disputed by the group although the relative weights differed. The weights for which there was most consensus are in future referred to as the consensus weights Figure 7.4. The range of weights suggested (Table 7.2) was tested in sensitivity analyses to determine if preferences would be affected.

Table 7.2. Range of weights suggested for the main criteria groups for the different zones. These were some of the weights used in sensitivity analyses. The "consensus" weights are in bold

Criterion group	Zone A			Zone B			Zone C		
Rehabilitation and sustainability	**100**	100	100	**80**	60	30	**50**	40	30
Economic growth	**40**	20	20	**90**	90	90	**50**	40	30
Social upliftment and equity	**60**	30	50	**100**	100	100	**100**	100	100

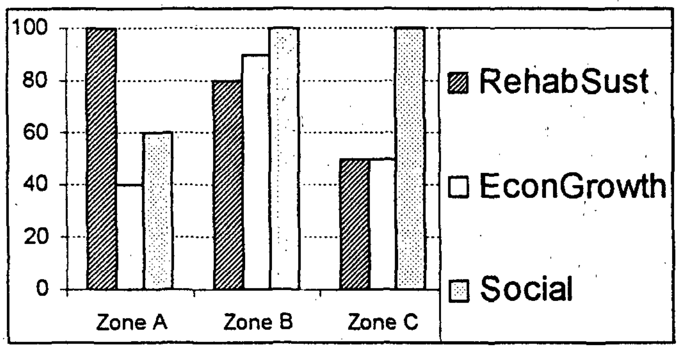


Figure 7.4. "Consensus" weights applied to the different zones for the three main criteria groups.

7.2 Results

In brief, the preferred scenarios for the three zones from the point of view of aggregated scores, were the removal of some plantations for community conservation in the upper zone (Scenario 7), some expansion of irrigation and community conservation (but neither to the maximum possible) in the middle zone (Scenario 3), and the allowing of harvesting of natural products in some of the commercial conservation areas in the lower zone (Scenario 4). This means that the preferred RS scenario is chosen in Zone A, the preferred SE scenario in Zone B, and the preferred EG and SE scenario in Zone C (Figure 7.5 and Appendix 7.1).

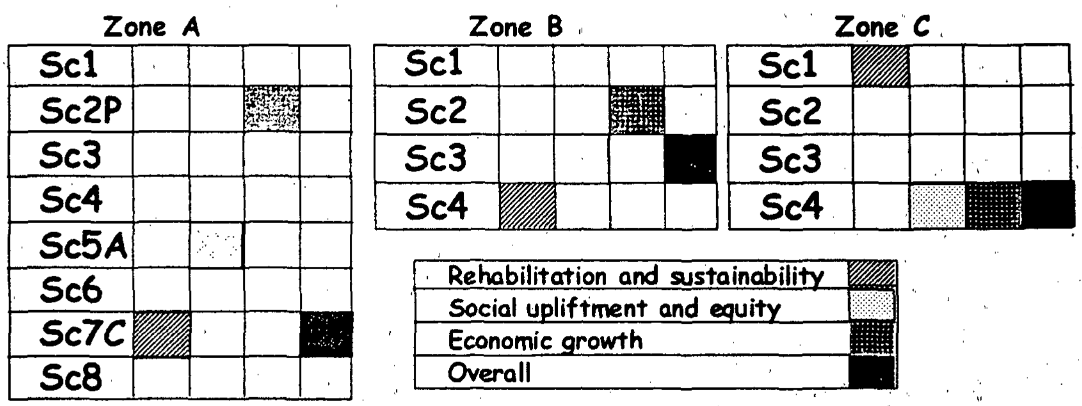


Figure 7.5. Preferred Scenarios from different points of view for each zone.

7.2.1 Preferred scenarios for Zone A

Using the consensus weights the preferred option overall was Scenario 7 - community conservation on 2497 ha of previously afforested area. Although Scenario 7 performed poorly in terms of the number of people formally employed, it had the highest level of informal employment (Figure 7.6), because harvesting of secondary and natural resources was allowed. The aggregated score for Scenario 7 was 42 % higher than the next preferred overall, Scenarios 4 which had approximately the same aggregate score as Scenario 5, which was preferred from the SE point of view. The scenarios divided into three groups, Scenario 7 standing alone as preferred, Scenarios 4 and 5 being equivalent and possible compromise solutions, and the remaining scenarios probably being unacceptable.

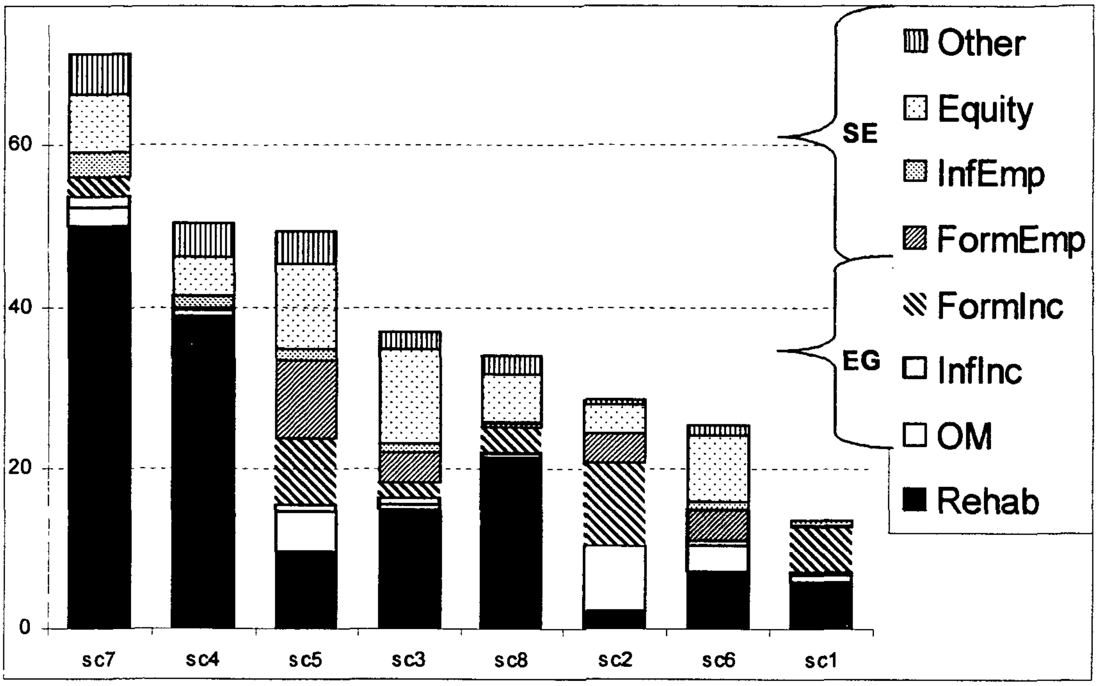


Figure 7.6. Relative contributions of criteria to overall scores of scenarios for Zone A.

7.2.2 Preferred scenarios for Zone B

Only Scenarios 2, 3 and 4 were compared for the middle catchment (Scenario 1 was not included, being a statement of the status quo without population growth). Using the consensus weights Scenario 3 was the preferred option overall and from the SE point of view (Figure 7.7). This implied some increase in permanent and annual irrigation, dryland farming and the expansion of conservation into this zone (all at the expense of grazing). The conservation model proposed was "community conservation", which allowed harvesting and, by assumption, employed 20% more people than that of the commercial conservation current in Zone C. Scenario 4, the projected status quo and preferred from the RS point of view ranked second overall, while Scenario 2, preferred from the EG point of view ranked third overall. There was little difference in overall score between Scenario 2 and 4.

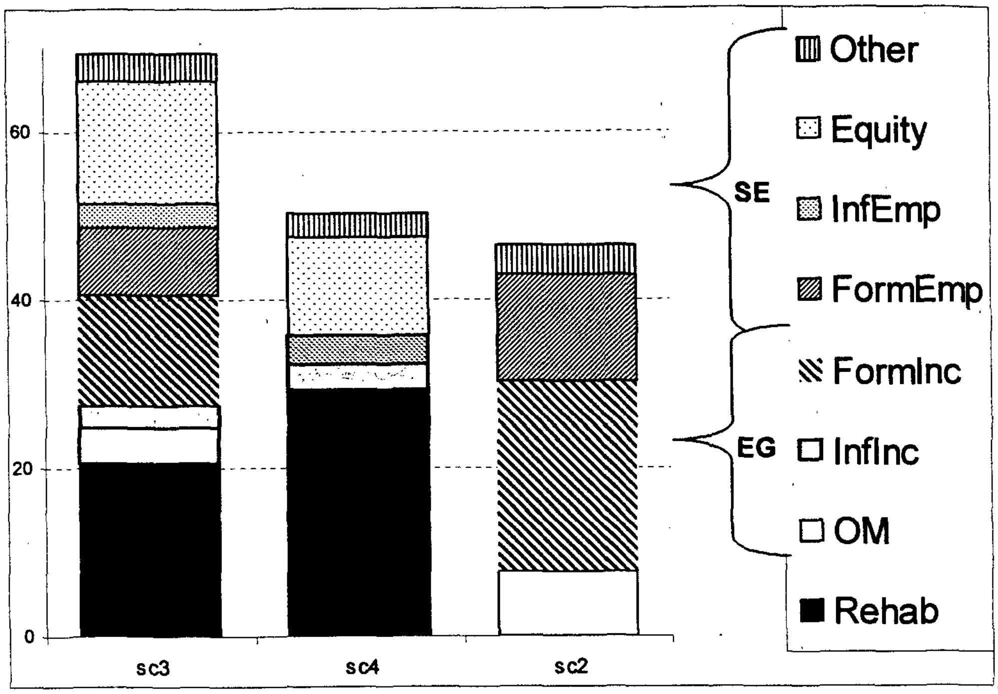


Figure 7.7. Relative contributions of criteria to overall scores of scenarios for Zone B.

7.2.3 Preferred scenarios for Zone C

Using the consensus weights, the preferred option overall was Scenario 4 with community management of some game reserves, and some harvesting allowed on 20% of other conservation areas. Scenario 2 (converting 20% of commercial conservation land to rangelands) was second most preferred overall (due to informal employment and earnings from resource harvesting), while Scenario 3 ranked third and Scenario 1 ranked fourth (Figure 7.8). There is a large gap in the overall score of Scenario 4 and those of the other three scenarios, and Scenario 1 and 3 are basically equivalent.

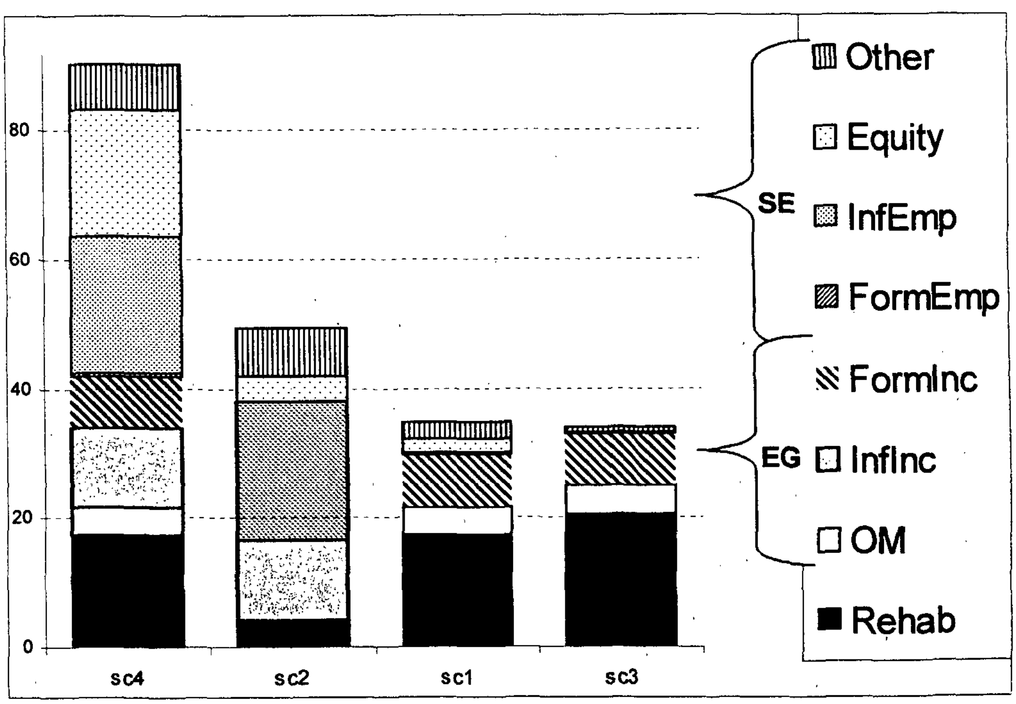


Figure 7.8. Relative contributions of criteria to overall scores of scenarios for Zone C.

7.2.4 Sensitivity to weight changes

Changing the weights of the three criteria groups within the range suggested in Table 7.2 made little difference to the preference order of the scenarios in all the zones and the preferred scenario remained the same. In Zone A, only when the ratio of weights for RS:EG:SE changed to (100:40:180), (100:151:60) or (100:108:108) did Scenario 5 become preferred to Scenario 7. Scenario 4, although second in overall score, never became preferred with changing weights at this level. Only if the ratio were (100:173:60) would Scenario 2 be the preferred option. In Zone B, only even more extreme weight changes would change the preferred option: for example, Scenario 4 would be preferred with a ratio of (255:90:100) and Scenario 2 would be preferred with a ratio of (80:293:100). In Zone C, even more extreme weight changes at this level are required to change the overall preferred option. Clearly, sensitivity to lower level weights also need to be tested, but are not illustrated here.

7.3 Discussion

7.3.1 Costs and benefits of preferred scenarios

A useful and intuitive formulation of a decision problem if that of specifying costs and benefits. This also helps to highlight areas where preferred scenarios could be improved before implementation. This may be done by comparing 'value profiles' or relative contribution graphics (e.g. Figure 7.6), or explicitly by comparing two scenarios. For example, in Zone A, Scenario 7 - converting some presently afforested land to conservation under natural land-cover, was preferred to Scenario 2 - converting some forestry land to irrigated tree crops, the latter being far more financially profitable than conservation. The benefits of preferring Scenario 7 to Scenario 2 stemmed from improvements in terrestrial and aquatic ecology due to the gain of 2497 ha of formal conservation land, the gain of R67 521 informal income, 649 informal employment opportunities, improved equity and other social issues. The costs of choosing Scenario 7 stemmed from a loss of R33 993 516 operating margin (OM), R393 527 formal income, and 741 formal employment opportunities (Table 7.3). The MCDA process translated these attribute differences into value differences, the overall value difference being 41 'points', i.e. Scenario 7 is 41 points better than Scenario 2. Applying the appropriate weights the positive contributions to this difference come from RS (47.7), informal income (1.5); and from aggregated informal employment, land equity and 'other' social issues (9.3). The negative contributions or costs of choosing Scenario 7, come from OM (5.9), formal income (8.0) and formal employment (3.6) (Table 7.3).

Table 7.3. Benefits and costs of choosing Scenario 7, the most preferred from the point of view of RS, rather than Scenario 2, the most preferred from the point of view of EG.

	BENEFITS in choosing 7					COSTS in choosing 7		
Criterion Group	**RS**	**EG**	**SE**			**EG**		**SE**
Criterion	Aggregate	InfInc	InfEmp	Equity	Other	OM	FormInc	FormEmp
Actual diff	2497 ha	R67 521	649 people			R33 993 516	R393 527	741 people
Difference in score	95.4	100.0	100.0	30.0	50	71.8	78.2	36.8
Weight			*0.24*					*0.76*
Weighted diff			24.4					27.8
Weight		*0.08*	*0.4*	*0.39*	*0.17*	*0.41*	*0.51*	*0.43*
Weighted diff		7.7	10.6	11.7	8.7	29.5	40.1	12.1
Weight	*0.5*	*0.2*	*0.3*	*0.3*	*0.3*	*0.2*	*0.2*	*0.3*
Weighted diff	47.7	1.5	3.2	3.5	2.6	5.9	8.0	3.6
Contributions to score diff	47.7	1.5	9.3			13.9		3.6
Overall aggregate score diff	58.6					17.5		
Overall						41.0		

7.3.2 Implied trade-offs, Value of conservation land

Simply viewing the global weights graphically (Figure 7.9) rather than numerically might help to clarify the accuracy of the swing weights given previously and will make trade-offs more apparent to the group(s). However, this view does not explicitly inform the group(s) what their weights imply with regards to what they were "willing to pay" for improvements on different criteria.

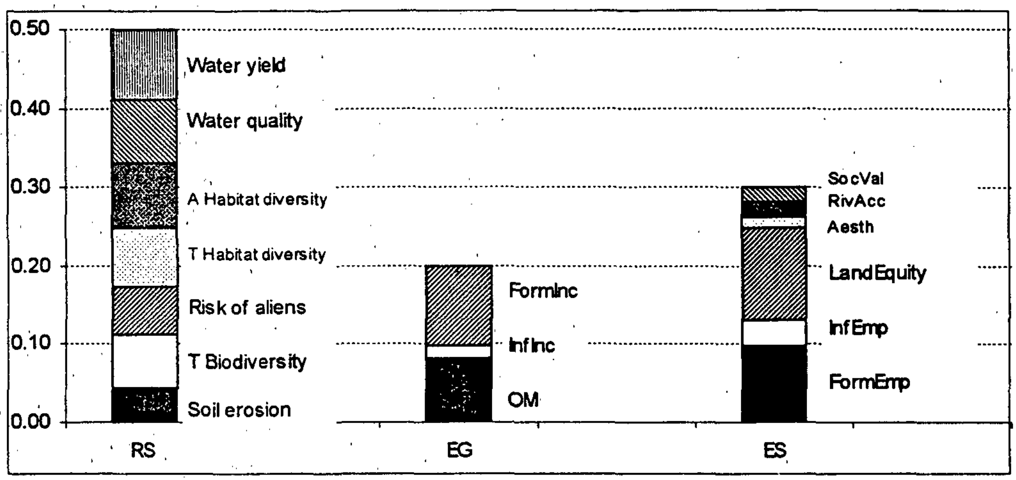


Figure 7.9. Relative contribution of criteria to the three criteria groups in Zone A.

Besides determining the implied trade-offs between any pair of criteria, the differences in values given to scenarios and criteria weights can be further examined in at least two ways. Firstly, given the current interest in the valuation techniques of resource and environmental economics, these trade-offs can be used to determine the implied monetary values of issues not explicitly valued in the study. These explicit trade-offs should be of interest to the group(s) and can help to ensure the internal consistency of the problem. For example, the weights given to RS and OM can be used to estimate a monetary 'value' for the non-monetary criterion group RS. Secondly, differences between specific scenarios can be examined to look at the implied 'monetary benefit' of choosing once scenario over another.

To determining the trade-offs using the values and weights in Table 7.4 for the criteria soil erosion (SEr, v_1) and OM (v_2) in Zone A, we would use (see Section 3.3):

1 value point of v_2 $= (x_2^* - x_2^\circ) / (v(x_2^*) - v(x_2^\circ))$ $= \text{R } k$

1 value point of v_1 $= (w_1/w_2) \times \text{R } k$ $= (0.18 \times 0.5 \times 0.5) / (0.41 \times 0.2) \times \text{R } k = 0.5538 \times \text{R } k$

However, as v_2 is non-linearly related to x_2 (the actual Rands of profit), the trade-off will be different between different x_2^* and x_2°. Therefore, average values need to be determined at appropriate intervals: we chose to calculate the average value at 20 point intervals. Thus,

the average Rand value of a point change in v_2 = R 920 274 between the interval 80 to 100,
the average Rand value of a point change in v_2 = R 465 064 between the interval 60 to 80,
the average Rand value of a point change in v_2 = R 235 022 between the interval 40 to 60,
the average Rand value of a point change in v_2 = R 118 770 between the interval 20 to 40,
the average Rand value of a point change in v_2 = R 60 021 between the interval 0 to 20,[9]

Thus, in the region of Scenario 7 (OM = 28.25), the trade-off between SEr and OM, gives 1 value point improvement in SEr compensating for a decrease of approximately R 65 775 in OM. The aggregate benefits from a 1 value point increase in RS, would compensate for a decrease of R 723 535 in OM. This might be easier to interpret as the trade-off made between two scenarios, taking all criteria into

[9] i.e. at the lower levels of x_2, a small increase has a bigger value than at the higher levels (see Figure 7.3)

account (Table 7.4). For example, the net benefits of Scenario 7 relative to Scenario 5 are worth about R 52 225 000. The RS benefits of Scenario 7 are worth about R 97 326 000 relative to Scenario 5. Although the relationship $v_1 = (w_1/w_2) \times v_2$ holds for all scenarios, the actual trade-off value between two criteria would depend on which Scenario were being considered, because of the non-linear relationship of OM value to Rands.

Table 7.4. Trade-offs between all criteria and OM translated into monetary terms in the region of Scenario 7, the total value of Scenario 7, and the benefit of Scenario 7 over Scenario 5.

Criterion	Contributing weights			Effective weight	(wl/w2)	Value of 1 unit change near Sc7 R'000	Value diff Sc7-Sc5	Benefit of Sc7 over Sc5 R'000
Soil Erosion	0.18	0.5	0.5	0.05	0.5538	R 65.8	100	R 10 982
Terr BioDiv	0.27	0.5	0.5	0.07	0.8307	R 98.7	80	R 13 178
Alien Risk	0.24	0.5	0.5	0.06	0.7384	R 87.7	80	R 11 714
Terr HabDiv	0.3	0.5	0.5	0.08	0.9230	R 109.6	80	R 14 642
Aqu HabDiv	0.32	0.5	0.5	0.08	0.9790	R 116.3	80	R 15 531
WaterQual	0.32	0.5	0.5	0.08	0.9790	R 116.3	50	R 9 707
WaterYield	0.36	0.5	0.5	0.09	1.0878	R 129.2	100	R 21 571
						R 723.5	RS subtotal	R 97 326
InfInc	0.08	0.2		0.0154	0.1876	R 22.3	46.96	R 1 747
InfEmp	0.24	0.43	0.3	0.03	0.3874	R 46.0	57.69	R 4 432
Aesthetics	0.27	0.17	0.3	0.01	0.1734	R 20.6	50	R 1 719
SocVal	0.36	0.17	0.3	0.02	0.2312	R 27.5	60	R 2 750
							Total 'benefits'	R 107 974
(OM)	(0.41)	(0.2)		(0.0821)	(1)	R 118.8	-31.82	R 6 310
FormInc	0.51	0.2		0.1	1.2491	R 148.4	-57.93	R 14 349
FromEmp	0.76	0.43	0.3	0.1	1.2018	R 142.7	-100	R 23 831
LandEqu	1	0.39	0.3	0.12	1.4303	R 169.9	-30	R 8 508
RivAcc	0.36	0.17	0.3	0.02	0.2312	R 27.5	-60	R 2 750
							Total 'costs'	R 55 749
							Net benefits	R55 225

Sources of value

Thus, although not designed to determine monetary values of non-market goods, an MCDA approach can provide them, providing that one of the criteria is 'naturally' a monetary criterion. MCDA would be classified as a stated preference approach, as are contingent valuation and conjoint scaling approaches used in environmental economics evaluations, as opposed to revealed preference approaches such as hedonic pricing and travel cost methods. Very few studies have compared different values arising from these different approaches. One study (Halvorsen *et al.*, 1997) compared contingent valuation, conjoint scaling and an MCDA technique and found that conjoint scaling and MCDA generally produced higher values. This is not all that surprising, as values are not constrained by income when applying MCDA.

In an environmental and resource economics formulation, the direct, indirect, and non-use or existence values of the options would need to be determined. This division of sources of value into direct, indirect, and non-use is a useful typology and may help to ensure that all types of value are considered.

Some *direct use values* were included explicitly in this study (some of which are often ignored). For example, income and employment from harvesting secondary and natural resources, and from small-scale irrigation on garden plots were included. *Indirect use value* was included the RS criteria, in particular, soil erosion, water yield, and water quality which indicate the extent of 'ecosystem services' supplied by the different scenarios. Most of the SE criteria include some aspects of indirect-use. Resource and environmental economics tools to determine indirect use values would require intensive data collection about ecosystem services (e.g. costs of supplying services such as flow regulation, water quality treatment, replacement of topsoil), and the implications of degraded environments on profits from various land-uses. A production function approach might be used where the effect of different levels of an environmental input are modelled in terms of various economic outputs (e.g. crop yields).

Existence value stems from the value people gain from knowing that a particular ecosystem, habitat, or species exists and is usually determined using contingent valuation surveys, asking questions about willingness to pay to conserve a particular environment, or accept in compensation for its loss. Willingness to pay for conservation of the upper catchment among the general public in the SRC would be likely to be low if determined in this way. However, value in terms of willingness to pay could derive from two sources. Firstly, the upper catchment forms part of the escarpment, many areas of which have high tourism value. The area could develop into a tourist destination to realise use value, and the increased awareness would increase existence value. Secondly, the managers and owners of the conservation areas in Zone C might have a high willingness to pay for changed land-use in the upper catchment. This has already been demonstrated in their partial funding of the project of which this study formed a part, and their willingness to litigate regarding forestry and irrigation practice in Zones A and B. Existence value plays a role in some of the RS (e.g. species richness) and SE criteria (e.g. land equity; scoring on this criterion was based more on the perception of land being accessible than on the redistribution of land). The flow of sources of value and associated criteria in the SRC is illustrated in Figure 7.10.

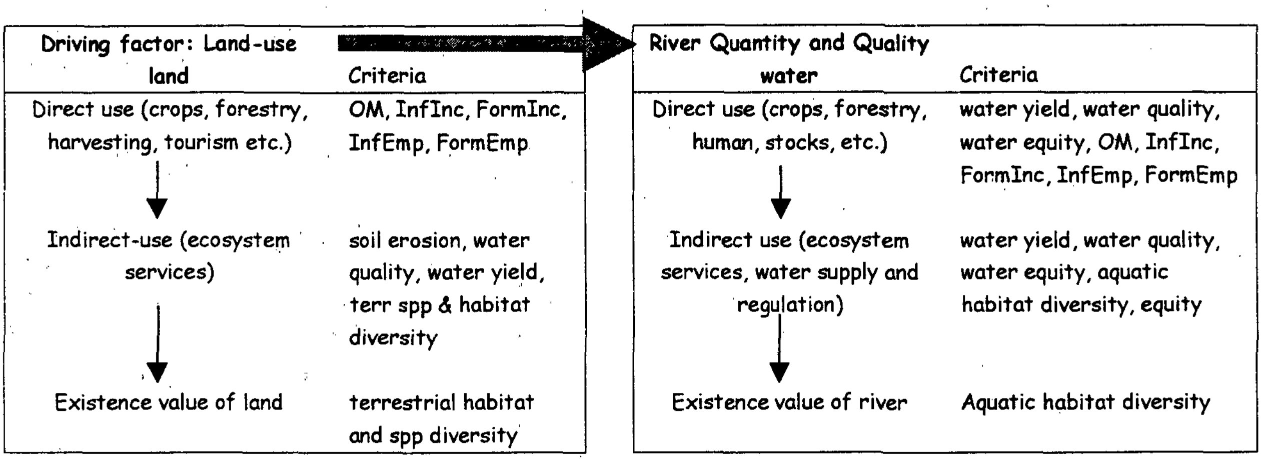


Figure 7.10. Sources of value for the catchment land-use scenarios.

The trade-off values obtained may well have been influenced by the way in which the weights were determined, e.g. comparing OM with SEr directly may have produced different results. It is the view of the authors that scores elicited without requiring a reference to ability or willingness to pay are more accurate representations of *preference*. However, subjecting these trade-offs to a 'reality check' might be worthwhile in certain situations (although the explicit introduction of these values may well introduce conflict into a group where there were none before). In addition, in this case, the actual costs of implementing the scenarios were not included in the analyses. However, whether translated into money or whether left as value scales, the relative values are important rather than the absolute values and these clearly underline the policy directions, and would be highly unlikely to change with realistic weight changes (see sensitivity analysis).

7.3.3 User-friendliness

The MCDA and associated techniques described here, are fairly simple and intuitive, and closely resemble common-sense approaches used in various applications (e.g. ranking, creating indices). The main advantage of using the more formal approach being that the theoretical basis may help to avoid some of the pitfalls of less rigorous approaches. Examples of these pitfalls include interpreting ranks as scores, and designating weights which do not relate to the range of consequences being considered.

Most of those involved found the use of thermometer scales fairly intuitive and were able to indicate the relative value of scenarios on the scale (see results of questionnaire, Chapter 6.3). However, it was clear that in some cases, verbal cues associated with scores would have been useful (e.g. poor, very good etc.). The value measuring techniques used could have been adapted for less numerate participants by using beans or stones to indicate scores, but was not necessary for this stage of the project where general public participation was not required.

Due to the time and funding constraints most of the results presented here could not be reported back to the project team for feedback and refinement. This was a serious drawback, as the team were therefore not fully aware of the usefulness of the results or able to further interpret and examine them (see comments from questionnaire, Chapter 6.3). This pointed to another problem with MCDA in that the printed medium is not always a very useful way to present results. The decision-support was perceived to be particularly useful for problem structuring and for the integration of different types of information.

7.3.4 Shortcomings

Some of the shortcomings in this study have already been highlighted:

- Time constraints meant that weights for criterion groups were estimated in the least taxing way by comparing groups directly, rather than by comparing criteria within groups.
- The number of scenarios could have affected results and their interpretation. In Zone B, only three scenarios were considered (as decided by the project team), and they were constructed (by the project team) in such a way that a 'middle ground' scenario was almost guaranteed to be 'best'.
- The division of the catchment into three zones was essential. Each of the preferred zonal scenarios was preferred from a different point of view (RS for Zone A, EG for Zone B, and SE for Zone C, (Figure 7.5). It was felt by the project team that, taken together, the scenarios would satisfy the objectives of integrated catchment management. However, combinations of scenarios across zones could have been examined in more depth if time permitted.
- The most important shortcoming was that their was no opportunity for feedback after the last workshop where certain scores and weights were finally obtained. This allowed no interactive sensitivity analysis, or review of values.

Appendix 7.1 Consequences of scenarios, scores and weights.

2.1 Zone A (weights are rescaled to sum to one)

	Rehabilitation and sustainability									Aggreg
	Terrestrial ecology				Aggreg	Aquatic ecology			Aggreg	
	Soil erosion	Biodiversity	Risk of alien invasion	Terrestrial habitat diversity		Aquatic habitat diversity	Water quality	Catchment water yield *		
Sc1 SQ	0	0	0	0	0	0	50	20	23.21	11.61
Sc8-25%	40	10	10	10	15.46	90	90	35	70.36	42.91
Sc2-perm irrig	0	0	10	0	2.42	10	0	10	6.79	4.61
Sc3-dryland	0	20	20	20	16.36	50	40	40	43.21	29.79
Sc4-graze	90	90	30	90	75.46	80	90	70	79.64	77.55
Sc5-ann irrig	0	20	20	20	16.36	20	50	0	22.5	19.43
Sc6-gardens	0	20	0	20	11.52	20	0	30	17.14	14.33
Sc7-conserv	100	100	100	100	100	100	100	100	100	100
weights	0.18	0.27	0.24	0.31		0.32	0.32	0.36		
weights					0.5				0.5	
weights										0.5

	Economic Growth						Aggreg
	Operating margin Total	Operating Margin 0-100	Informal Earnings Total	Informal Earnings 0-100	Formal Income Total	Informal Income 0-100	
Sc1 SQ	1 812 728	11.45	65 303.3	32.11	346 727	53.62	23.66
Sc8-25%	1 414 817	4.19	57 427.3	17.16	261 096	31.29	19.08
Sc2-trees	37 209 420	100	49 551.4	0	624 925	100	92.3
Sc3-dryland	1 664 694	8.95	75 101.9	48.37	224 198	19.3	17.29
Sc4-graze	1 226 402	0	81 579.5	57.99	179 447	1.767	5.37
Sc5-crops	9 526 301	60.07	78 184.7	53.04	482 982	79.72	69.6
Sc6-gardens	4 824 824	40.14	71 787.1	43.12	175 465	0	19.79
Sc7-cons	3 215 904	28.25	117 072.3	100	231 398	21.78	30.46
weights		0.4104		0.077		0.513	
weights							0.2

	Social upliftment and equity										Aggreg
	Employment				Aggreg	Equity	Other			Aggreg	
	Formally employed Total	Formally employed 0-100	Informally employed Total	Informally employed 0-100		Land Equity	Aesthetics greenspace	River access	Social value of harvesting		
Sc1 SQ	271.9	2.624	627.71	23.077	7.61	0	40	30	0	21.82	7.1
Sc8-25%	271.9	2.624	552.8	11.538	4.8	50	80	40	30	47.27	29.87
Sc2-trees	959.6	36.77	477.89	0	27.81	30	50	0	40	28.18	28.73
Sc3-dryland	984.6	38.01	702.62	34.615	37.18	100	10	70	40	42.73	62.73
Sc4-graze	235.5	0.816	788.77	47.885	12.29	40	50	60	90	68.18	32.85
Sc5-crops	2233	100	752.56	42.308	85.94	90	50	100	40	64.55	83.81
Sc6-gardens	984.6	38.01	690.13	32.692	36.71	70	0	50	50	36.36	49.68
Sc7-cons	219	0	1127.1	100	24.38	60	100	40	100	78.18	47.67
Weights		0.756		0.2438		1	0.27	0.36	0.36		
Weights					0.4348	0.39				0.17	
Weights											0.3

*Estimated as hydrology unavailable

2.2 **Zone B** (weights are rescaled to sum to one)

	Rehabilitation and sustainability									Aggreg
	Terrestrial ecology				Aggreg	Aquatic ecology			Aggreg	
	Soil erosion	Bio-diversity	Risk of alien invasion	Terr habitat diversity		Aquatic habitat diversity	Water quality	Catchment water yield *		
Sc1-not used										
Sc2-Max pot	0	0	0	0	0	0	0	0	0	0
Sc3-realistic	85	100	25	100	84	90	50	70	54	69
Sc4-SQproject	100	95	100	95	78	100	100	100	100	99
Weights	0.42	0.33	0.13	0.13		0.32	0.32	0.36		
Weights					0.5				0.5	
Weights									0.3	

	Economic Growth						Aggr
	Operating margin Total	Operating Margin 0-100	Informal Earnings Total	Informal Earnings 0-100	Formal Salary/Wage Total	Salary 0-100	
Sc1-not used							
Sc2-Max pot	146764712	100	2315999	0	2520835	100	91
Sc3-realistic	126474335	55.4	2462001	89.04	1909203	58.16	60
Sc4-SQproject	105118599	0	2480598	100	1297398	0	9
Weights		0.23		0.0912		0.678	
Weights							0.333

	Social upliftment and equity												Aggr
	Employment					Equity	Other						
	Formally employed Total	Formally employed 0-100	Informally employed Total	Informally employed 0-100	Aggr	Land Equity	Aesthetics greenspace	River access	Infra-structure	Crime	Social value of harvesting	Agg	
Sc1not used													
Sc2Max pot	28920	100	22189	0	79	0	30	0	100	100	0	52	43
Sc3realistic	26559	62.64	23629	85.64	68	100	70	70	60	60	20	50	77
Sc4SQproj	22601	0	23870	100	21	80	80	100	0	0	100	44	48
Weights		0.79		0.21		1	0.05	0.13	0.32	0.19	0.32		
Weights					0.43	0.39						0.17	
Weights													0.37

*Estimated as hydrology unavailable

2.3 Zone C (weights are rescaled to sum to one)

	Rehabilitation and sustainability									Agg
	Terrestrial ecology					Aquatic ecology				
	Soil erosion	Terr spp diversity	Alien invasion	Terr habitat diversity	Agg	Aqu hab diversity	Water quality	Catch water yield *	Agg	
Sc1-Status Qu	100	0	100	0	66	100	100	100	100	83
Sc2-20%graz	0	100	0	100	35	0	0	00	0	17
Sc3-Many	70	0	70	10	48	90	95	90	92	70
Sc4Man+Harv	70	0	70	10	48	90	95	90	92	70
weights	0.31	0.17	0.34	0.17		0.32	0.32	0.36		
weights				0.5				0.5		
weights										0.25

	Economic Growth						Agg
	Operating margin Total	Operating Margin 0-100	Informal Earnings Total	Informal Earnings 0-100	Formal Income Total	Salary 0-100	
Sc1-not used	76492296	100	0	0	1334143	95.5	49
Sc2-Max pot	63525794	0	356519	100	1111643	0	50
Sc3-realistic	75694862	94.4	0	0	1345733	100	50
Sc4-SQ project	75694862	94.4	356202	99.9	1345733	100	99
weights		0.18		0.49		0.33	
weights							0.25

	Social upliftment and equity										Agg
	Employment					Equity	Other				
	Formally employed Total	Formally employed 0-100	Informally employed Total	Informally employed 0-100	Agg	Land Equity	Aesthetics green-space	River access	Social value harvest	Agg	
Sc1not used	1668	79.3	0	0	2	0	100	0	0	9	2
Sc2Max pot	1612	0	3460	100	98	20	0	100	90	86	65
Sc3realistic	1682	100	0	0	2	10	100	30	20	32	10
Sc4SQproj	1682	100	3425	98.9	99	100	100	60	100	82	96
Weights		0.02		0.98		1	0.1	0.5	0.45		
Weights					0.44	0.39				0.17	
Weights											0.37

* Estimated as hydrology unavailable

Chapter 8. Other land-use planning examples

8.1 Forestry and land-use decisions in the northern Eastern Cape.

Although this was not primarily a water resource problem, it is included here, as the problem included many similar issues, and demonstrates a different application of the SBPP/MCDA process. The impetus for the work came from a widely felt need for a more streamlined afforestation permit application system and, more specifically, from the rapidly increasing afforestation in the northern Eastern Cape of South Africa. This was occurring mainly in the Maclear district (ca. 200 000 ha), which stretches approximately 80km along the southern foothills of the Drakensberg mountains, in an area which typifies the conflicts which often arise.

Approximately 1½ million hectares of South Africa is presently under commercial plantations of non-indigenous trees. Much of this afforestation has occurred on the eastern escarpment at the edge of the inland plateau on land which was naturally afro-montane grassland. The Maclear district is at the southern end of the Eastern Mountain 'hotspot' of plant diversity, one of eight recognised for southern Africa (Figure 8.1). About 30 % of the plant species are endemic and about 5 % of the "hotspot" is formally conserved, almost exclusively at the northern end (Cowling and Hilton-Taylor, 1994). The vegetation is primarily *Themeda triandra* Forssk. Grassland with some montane forest, scrub and *Protea* savanna (Armstrong, 1996, Armstrong and van Hensbergen , 1997). Afforestation, overgrazing and increased crop-farming are among the main threats to afro-montane grasslands throughout Africa, leading to its identification as one of the three most threatened habitats in Africa. In response to this, the World Wide Fund for Nature (WWF) funded a conservation evaluation of the afro-montane grasslands in the area, which was carried out by the Department of Nature Conservation of the University of Stellenbosch (Armstrong, 1996, Armstrong and van Hensbergen, 1997).

North East Cape Forests, a consortium managed by Mondi, had by the time of this study (1995/1996) acquired approximately 75 000 ha in the region and had planted mainly pine trees on some 38 000 ha, indicating on average that afforestability of the land was about 50 %. This area under afforestation would be insufficient to support the operation of a pulp-mill, but could support the operation of a fairly large sawmill (output of more than 200 000 m^3). With the idea of having additional plantations available for a future pulp-mill, Mondi had begun negotiations for the establishment of community forestry projects in the former Transkei. However, given the uncertainty of future demands and the fact that much of the land already owned by Mondi in Maclear is not ideal for afforestation (implying larger costs), North East Cape Forests were seeking permission to extend afforestation within the district.

Economic pressures led many Maclear farmers to sell at the time of initial forestry expansion in 1989, as only larger farms seemed viable after a prolonged drought. The change from predominantly cattle grazing and a farming community to commercial forestry has changed the economic and social structure of the area considerably. Further relevant factors are that the Eastern Cape has the second highest unemployment figures in the country (around 45%), and the relatively wealthy Maclear district is bordered on the east by the Transkei where population pressures, overgrazing and erosion are more extreme. In addition, political changes have seen Maclear district local councils pass from the control of commercial farmers to the African National Congress, who were seeking upliftment of previously disadvantaged communities.

Commercial forests have the potential to seriously restrict run-off into public streams and rivers both directly and through the invasion of other areas by the exotic species. Landowners are required to apply to the DWAF for permits to plant forests. The functioning of the permit system had recently changed to allow for representations from all affected parties which are reviewed by the multi-party Afforestation Review Panel in each province. Although primarily concerned with affects on run-off, a full impact assessment (IA) could be recommended for each application in order to assess other impacts as well. The inclusion of representations from land-owners and the IA process has slowed down the operating of the permit system and also means that small growers may potentially face the very high costs of funding the IA. For this reason, a government Green Paper identified the need for a more streamlined approach to the issuing of permits, which, while still allowing for participation, does not imply such large costs. Our study was seen as contributing towards this aim.

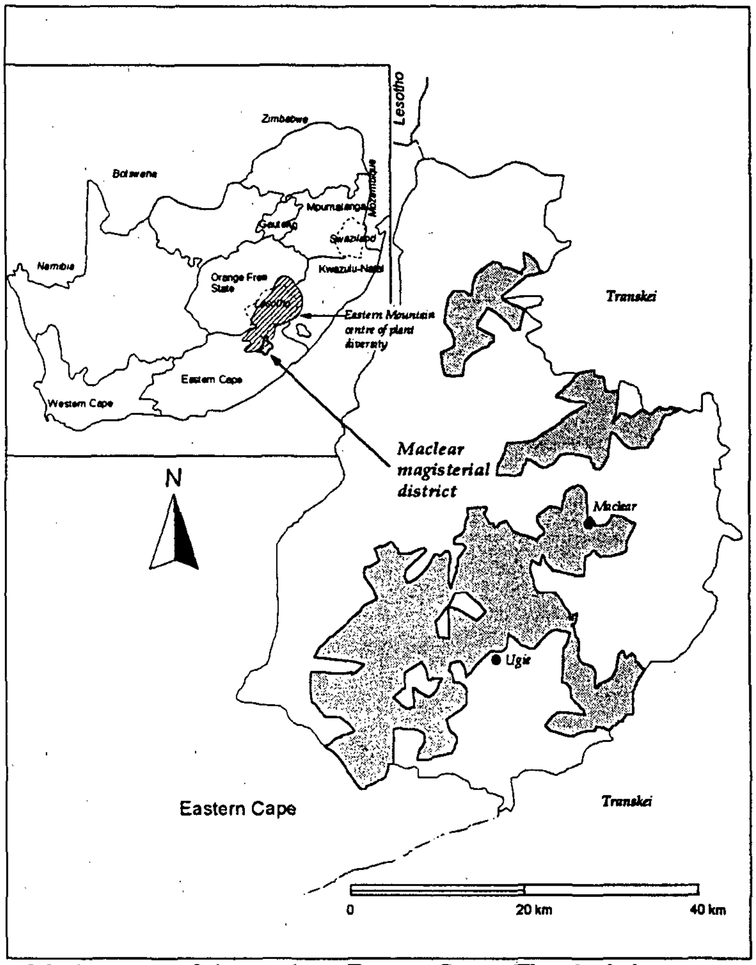


Figure 8.1. Map of the Maclear area of the northern Eastern Cape. The shaded areas are those presently owned by the commercial forestry company.

8.1.1 Methods

The SBPP/MCDA process followed the stages outlined in **Chapter** 3 during four workshops. Through an informal process various points of view were identified as relevant to the problem and representatives were found to attend the workshops or contribute if they could not attend (Table 8.1).

Table 8.1. Points of view, stakeholders and their representatives.

POINT OF VIEW /STAKEHOLDER	REPRESENTATIVES
Commercial forestry	North East Cape Forests
National Forestry planning	Department of Water Affairs and Forestry
Agricultural interests	Dept of Agriculture and Land Affairs, Eastern Cape Province.
Nature conservation	Dept Nature Conservation, Eastern Cape. Dept Nature Conservation, University of Stellenbosch
Social interests	Mayors and Town Clerks of Maclear and Ugie
Hydrology	Environmentek (Council for Scientific and Industrial Research)

Identifying values and appropriate spatial scales for decision-making

The permit system operated on a farm by farm basis, and this was the level which was developed during the first workshop. However, perhaps one of the most useful outcomes of this workshop, was the agreement that this was not an appropriate level at which to make decisions, unless reference could be made to larger scales of decisions, termed the meso-scale (which came to be defined as the Maclear district, with some reference to neighbouring districts) and the macro-scale (which was generally accepted as referring to the national level). It was acknowledged that micro-scale (farm level) decisions would always be necessary, but needed the context of a larger scale in order to avoid sub-optimal incremental decisions. The following three workshops, therefore focused on the meso-scale and re-assessed the criteria of interest, developed hypothetical scenarios for evaluation, determined the criteria ranges and evaluated the scenarios at this scale.

Scenario development

Before and during the second, third and fourth workshops, six scenarios were developed which covered a realistic range of possible future developments at the "meso-scale" (the Maclear district). These were developed to a level of detail sufficient for the workshop participants to compare and distinguish between them. As the scenarios were refined, the impacts or criteria levels were specified in more detail, so that value functions could translate the related quantitative information to a value (e.g. number of land-types preserved), while others were evaluated directly (e.g. personal well-being). Those impacts or criteria which were well specified earliest in the process were those which related to work already completed in the district viz. the WWF wildlife indices study (Armstrong and van Hensbergen, 1997) and a study of the hydrological affects of afforestation on the quaternary catchments (Forsyth *et al.*, 1996).

Some criteria remained unspecified until the fourth and final workshop, specifically those relating to economic impacts. Further research allowed these to be included in the scenario descriptions for this workshop, which meant that the scenarios could be evaluated on the basis of all the criteria specified earlier in the process (Figure 8.2). An issue which arose at the third workshop was the size of the multiplier effect of the forestry primary processing industries. Multipliers were included in the scenario descriptions, by including "sub-scenarios" of a range of possible multiplier effects. It was agreed at the fourth workshop that only local multiplier effects were relevant, with the understanding that decisions on a national scale would include national level multipliers, either as effects on GDP or as employment multipliers or both. Only evaluations concerning Sub-scenario 1 (multipliers of all land-uses and processing are 1.2) are included in this report as the most likely situation.

The farms of the district were entered into an Excel spreadsheet, designated as either agriculture or forestry and linked to information and calculations relating to area, species present, employment rates, landtypes etc. The designation could be changed using Excel's "scenario" function, allowing all calculations to be updated for different scenarios.

Input from the conservation representatives led to further adjustments during the course of the fourth workshop, namely the addition of a conservation constraint to the effect that no further afforestation should occur on land-types 2, 4 and 9 which had high biodiversity and endemicity. This led to the addition of Scenarios 4a, 5a and 6a, which were in all respects the same as Scenarios 4, 5 and 6 apart from this constraint. As this brought the total number of scenarios to 9, Scenarios 2 and 3 were not specifically evaluated during the workshop, as they were perceived to be not very different from Scenario 4, but where possible evaluations made subsequently are included for completeness (Appendix 8.1). In summary, seven scenarios were evaluated at the fourth workshop, based on Sub-scenario 1's multiplier effects. These were Scenarios 1 (*status quo*), 4, 5, 6, 4a, 5a and 6a.

Selection of criteria and the development of the value tree

Criteria were identified during "brainstorming" sessions during the workshops. These sessions included an "electronic brainstorming" session using the GroupSystems software (Ventana Corporation, 1994) in the decision room of the University of Cape Town during the second workshop. In this system, all participants are connected to a small network around a table, can type their ideas at their computer, which then appear anonymously on the screens of all participants. This has the advantage of anonymity, of avoiding dominance by stronger personalities and of allowing the rapid generation of many ideas. The ideas were grouped, categorised and organised into a value tree, which was further developed and refined before and during the remaining workshops (Figure 8.2). The lower level criteria (on the right hand side) are the criteria used in the evaluation. The higher level boxes may either be considered as categories or as outcomes of the combined effects of the criteria beneath them.

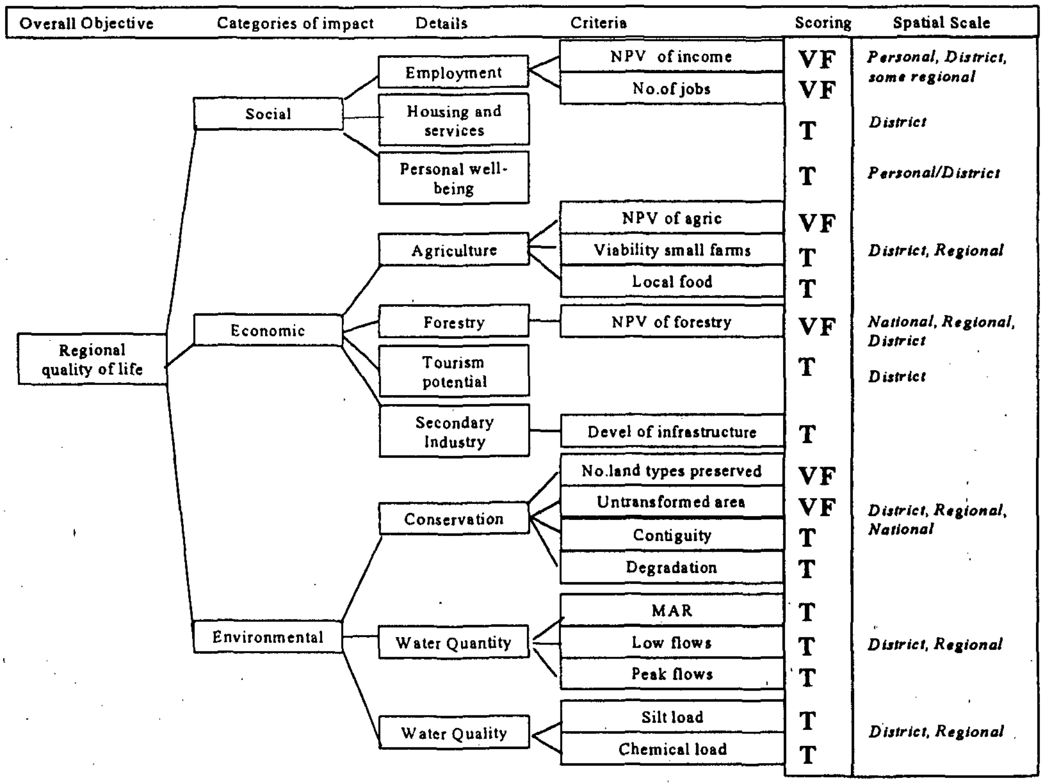


Figure 8.2. Value tree constructed from the criteria and categories defined during the workshops. VF= Value function scoring, T= Thermometer scale scoring.

Consequences of scenarios, scoring

New research had to be completed in order to obtain adequate descriptions of the scenarios and criteria ranges for some criteria, in particular the criteria concerning economic impacts. Three criteria were expressed as net present value (NPV). It is worth noting here that the term NPV is usually associated with an "economic" analysis, but in this case refers to a "financial" analysis. A full economic analysis of, for example, forestry income, should include externalities such as social and environmental impacts, the effects of subsidies, price controls and exchange rates etc. In our example, at least some of these are explicitly included in the other criteria considered (e.g. the conservation and social criteria). We see this as one of the advantages of MCDA, in that these aspects are often totally ignored or only mentioned as parallel information rather than included in an economic analysis. Already completed research (e.g. Armstrong, 1996 and Forsyth *et al.*, 1996) was used to derive certain of the other criteria ranges.

Scores on a 0 to 100 thermometer scale were given to the scenarios based on each of the criteria separately using the VISA software. Linear value functions were used for all criteria relating to NPV, income and employment, and a non-linear value function to relate "number of land-types preserved" to value (Figure 8.3a,b) Direct scoring was used for all other criteria.

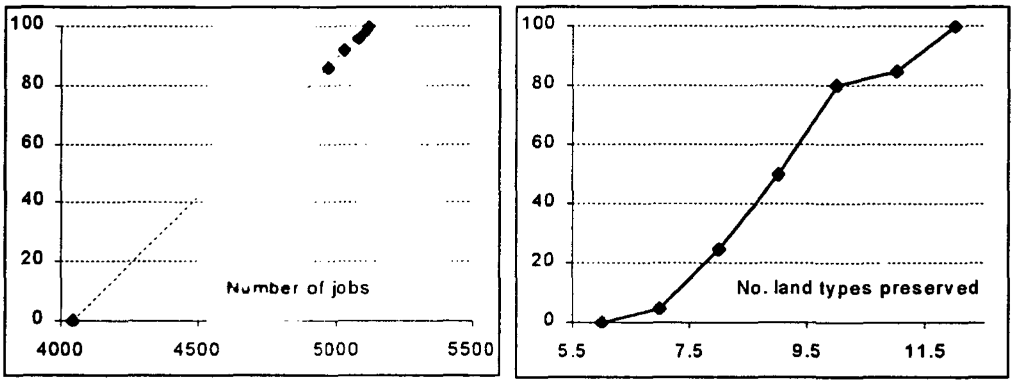


Figure 8.3 (a) The linear value function, and a (b) non-linear value function.

Criteria weights and aggregation of scores

Once scores for the various alternatives were assigned, relative weights were assigned to the criteria. Criteria within a category were first compared, and then the relative importance between the different categories was compared. For example, within the category 'conservation', 'number of land types preserved" was felt to be most important in some sense and the impact of a swing from the worst level (Scenarios 5 and 6) to the best level (Scenario 1) was perceived to be twice as important as a swing from worst to best on the next most important criterion, 'contiguity'. These weights were then normalised to sum to one. The relative importance of the three criteria groups (social, economic, and environmental) was determined by the group, and it was agreed that within the decision context, the criteria relating to social issues (specifically employment) were most important and this category was given twice the weight of the other two categories (Figure 8.4). Once weights were assigned to all the criteria, the scores could be aggregated at different levels of the hierarchy, based on a weighted summation (Chapter 3, equation (3.1)). The VISA software automatically completed the aggregations according to the hierarchy of the value tree (Figure 8.2). Scores, aggregated scores and weights are reported in full in Appendix 8.1.

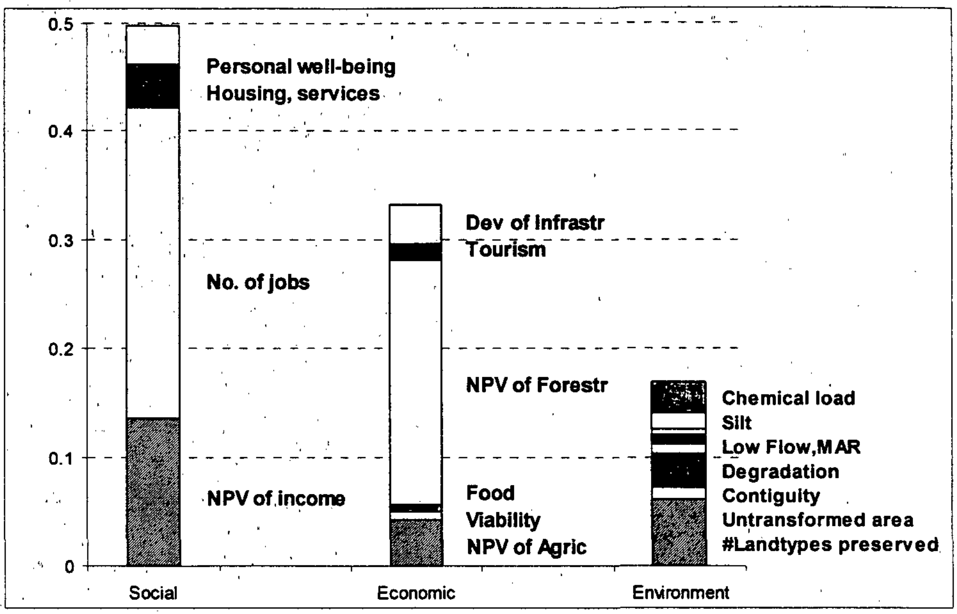


Figure 8.4. Weights of three criterion groups, with contributions by criteria.

8.1.2 Results

Scenario 5 was generally the most preferred for the criteria relating to employment, and forestry NPV, Scenarios 1 and 6 were the least preferred from these perspectives. Scenario 1 was preferred for the criteria relating to the environment (both conservation and hydrology) and for NPV of agricultural production. The other Scenarios rated somewhere in-between, perhaps not being 'best' choices on any one criterion, but offering potential compromises as they were seldom the worst option. Scenario 5a was somewhat preferred to Scenario 5, while Scenario 6 was least preferred overall (Figure 8.5).

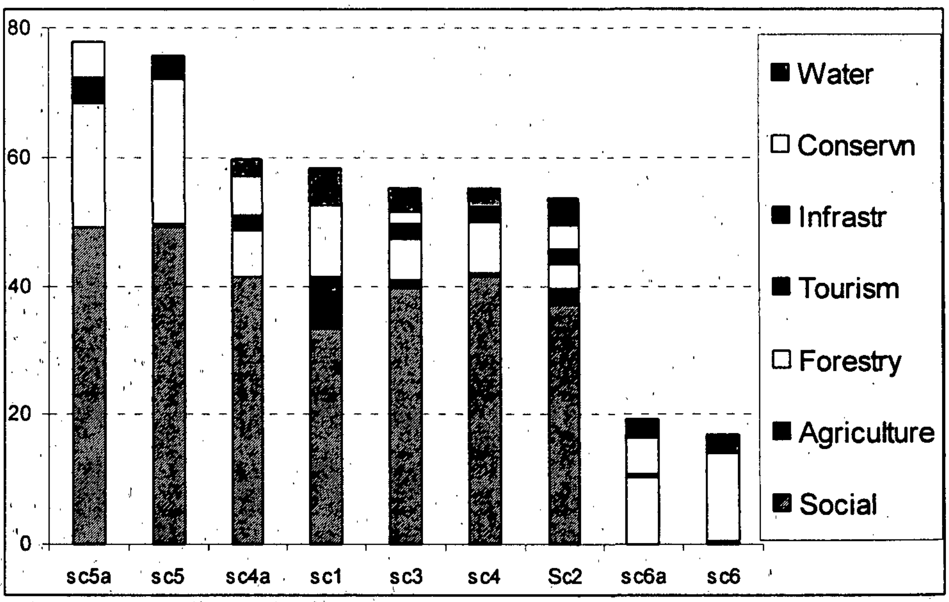


Figure 8.5 Aggregate scores, showing contributions from lower level criteria.

Value profiles and aggregated scores

The 'value paths' showing scores for a number of criteria at the same level of the hierarchy were also considered. In this instance the option preferred overall (Scenario 5a) is a reasonable potential compromise, as it is not the 'worst' scenario for any category, and is in fact the most preferred option for the social category, and the second most preferred for the economic category. However, the economic preferences were not clear-cut due to the conflict between agriculture and forestry. Scenarios 5a is in fact the least preferred option from the agricultural point of view. The difference between Scenario 5 and 5a, as far as agriculture is concerned, was based on the argument that, if the forestry company were not allowed to further afforest any of land-types 2, 4, and 9, then they *may* buy farms which are presently used for arable farming and so the NPV of agriculture *may* be reduced. In fact, this is unlikely to be the case, as a profitable farm is unlikely to be sold, and so Scenarios 5a and 5 may in fact be equivalent from an agricultural point of view (i.e. both are worst). The weight assigned to forestry relative to agriculture was based on the range of impacts across the scenarios: this was larger for forestry than for agriculture, and so a larger weight was given.

As an aside, if, a pulp-mill were not constructed, another compromise would have to be sought within the original Scenarios 1, 2, 3, 4 and 4a, which do not include pulp-mills. In that case, Scenario 4a would be preferred, and Scenario 1 would be a 'close second'. There is little to choose then between Scenarios 3, 4, and 2, which is one of the reasons that these were not fully analysed during the workshop, as they were perceived to be too similar to Scenario 4.

The implication of conservation constraints

Some of the more interesting aspects of the process are revealed by exploring the implicit trade-offs at various levels of the hierarchy. The difference between Scenarios 4, 5 6 and 4a, 5a, 6a is that there are conservation constraints built into 4a, 5a, and 6a (no afforestation on the remainder of land-types 2, 4, and 9). This implies that in order for the forestry company to reach its desired level of afforestation it *may* be forced to afforest on land less suitable for afforestation, which in turn *may* imply increased costs in terms of harvesting, and decreased mean annual increment (MAI) etc. The workshop participants agreed that the amount of land involved would be approximately 5 000 ha (approximately 10 % of the total afforestation, or a half to two thirds of any new afforestation). The MAI could conceivably be reduced from 15 to 12 or 10 m^3/ha/a. Considering the "worst case" of a change to an MAI of 10 m^3/ha/a, this loss in production over 25 years would translate to a NPV of about R 16×10^6. In order to justify a preference for alternative 5 over 5a, however, the loss in income discounted over 25 years would have to be greater than around R33 x 10^6. In other words, in order to justify *not* adhering to the conservation constraints, the forestry company would have to prove a potential loss of greater than R33 x 10^6. Another way of considering this, is that the remaining untransformed land types 2, 4, and 6 will have a value of R33 x 10^6 discounted over the next 25 years. This value would stem from their present rarity, their threatened status, ecosystem services provided, habitat value, existence value, recreation value etc, as embodied in the conservation, hydrology, and social criteria. In the Armstrong and van Hensbergen (1997) study, the importance of these land-types stemmed from the presence of endemics and the rarity of the land-types in the area. As a rough comparison of values, in a recent article Costanza *et al.* (1997) estimated from various sources, global figures for the value of various habitats in terms of ecosystem services etc. About 5000 ha of grasslands, at R244/ha/a or R1098/ha/yr, discounted over 25 years, would have an NPV of around R60 x 10^6.

Implied trade-offs

Following the same procedure as in (Chapter 7) using NPV of forestry as the standard monetary criterion reveals the trade-offs shown in Table 8.2. In this case the NPV of forestry had a linear value function, and so the trade-off does not depend on the attribute level. The relative contribution of the different criteria were shown in Figure 8.4.

Table 8.2. Monetary value of 1 value point changes in each criterion. **Trade-offs between Sc5a and Sc5.**

Criterion	Contributing weights			Effective Weight	(w1/w2)	Value of 1 pt change	Val diff (sc5a - Sc5)	Rand diff
NPV of Forestry		0.677	0.332	0.225		R 1 150 000		
#landtypes preserved	0.545	0.662	0.169	0.061	0.2713	R 311 970	80	R24 957 568
Untransform Area	0.099	0.662	0.169	0.011	0.049	R 56 670	9	R 510 027
Contiguity	0.279	0.662	0.169	0.031	0.139	R 159 706	25	R 3 992 639
Tourism		0.046	0.332	0.0153	0.068	R 78 139	15	R 1 172 083
						Total gains		R30 632 317
NPV Agric	0.754	0.169	0.332	0.0423	0.188	R 216 455	-8.7	-R 1 882 216
Viability of farms	0.124	0.169	0.332		0.031	R 35 597	-6	-R 213 584
Local food prodn	0.122	0.169	0.332	0.0068	0.0305	R 35 023	-6	-R 210 139
NPV Forestry		0.677	0.332	0.2248	1	R1 150 000	-13.9	-R16 000 000
Degradation	0.077	0.662	0.69	0.0086	0.0383	R 44 076	-10	-R 440 764
						Total losses		-R18 764 703
						Net Gain		R 11 885 614

Sensitivity to weights

Changing the importance weights of some of the criteria also affected the implied cost of not adhering to the conservation constraints as discussed in the previous section. For example, if the weight of conservation increased, or the environment category slightly increased, the implied cost of Scenario 5a in terms of lost forestry earnings would decrease. In general the overall preferences, as tested with VISA and Excel, were insensitive to changes in weights,. However, increasing the weight on the environmental category by 14% made Scenarios 4a and 1 equally preferred. Note that the weights of the other two categories would be slightly reduced to compensate as the weights are normalised. If the weight given to the economic category were increased by 39 %, then Scenarios 5 and 5a would be equally preferred. Increasing or decreasing the weights on the social category, had no significant impact on the overall preferences.

8.1.3 Discussion

The SBPP/MCDA process appeared to be of interest to those involved, and played a role in informing other processes aimed at decision making at a more "macro-scale". The implicit trade-offs and the values of scenarios from different points of view were of particular interest. The flexibility of the process was useful, as once a certain level of detail was available scenarios could be reasonable easily adjusted. Problems encountered in using this approach were more operational than methodological. For various reasons, the four workshops were spread over an extended period of time, and so impetus was lost in-between, and participants changed. Very few followed the process from beginning to end, and those who did not do so, would be less likely to appreciate the positive aspects. For the most part people were willing to accept others' points of view and direct conflict and disagreement was avoided.

8.2 Preliminary Assessment of the Expansion of the Baviaanskloof Wilderness Area[10]

The study aimed to assess the potential consequences of the proposed expansion and consolidation of the western sector of the Baviaanskloof Wilderness Area (BWA), Eastern Cape, relative to other land-uses. The feasibility study was intended to include an SBPP/MCDA process and evaluation and an environmental and resource economics study of the proposal and variations. The economics study was aimed at determining economic impacts (e.g. to towns in the area), direct use values (e.g. direct use of

[10] This report was originally written by Alison Joubert, Brad Smith and Kirsten Neke (the latter two of the FitzPatrick Institute, University of Cape Town), and partially funded by Vodacom and Telkom.

BWA by tourists), indirect use values (e.g. the value of water and ecological services of the BWA), and non-use values (e.g. value of knowing that a wilderness area exists). These were to provide input into the SBPP/MCDA process. However, due to budget changes only a preliminary assessment could be completed using available data mainly from StatsSA (1981 to 1996), Kruger (1997) and Clark (1998), and the limited input obtained in one public meeting and one 'working committee' meeting.

A proposal had been put forward to expand the present BWA through the acquisition of the private land (ca. 54 000ha) situated between the two western 'arms' of the BWA (Figure 8.6). The expanded BWA would be zoned so that the present BWA could retain its wilderness character, while higher intensity tourism could occur in the newly acquired areas. This farm land is referred to as the Kloof. If the proposal for consolidation of the western sector were accepted, with an area of about 250 000 ha, the BWA would become the country's third largest wilderness area after the Kruger National Park and the Kalahari Gemsbok (Ash 1999). The proposal suggested that there would be numerous socio-economic and conservation benefits. These included: increased conservation value, management efficiency and cost-effectiveness of the park itself, increased water availability for downstream use, improved riverine health, increased job opportunities directly and indirectly generated, increased economic activity and Gross Geographic Product (GGP) in the region and improvement of government services in the region (also see Clark 1998). Further background is given in Appendix 8.2.

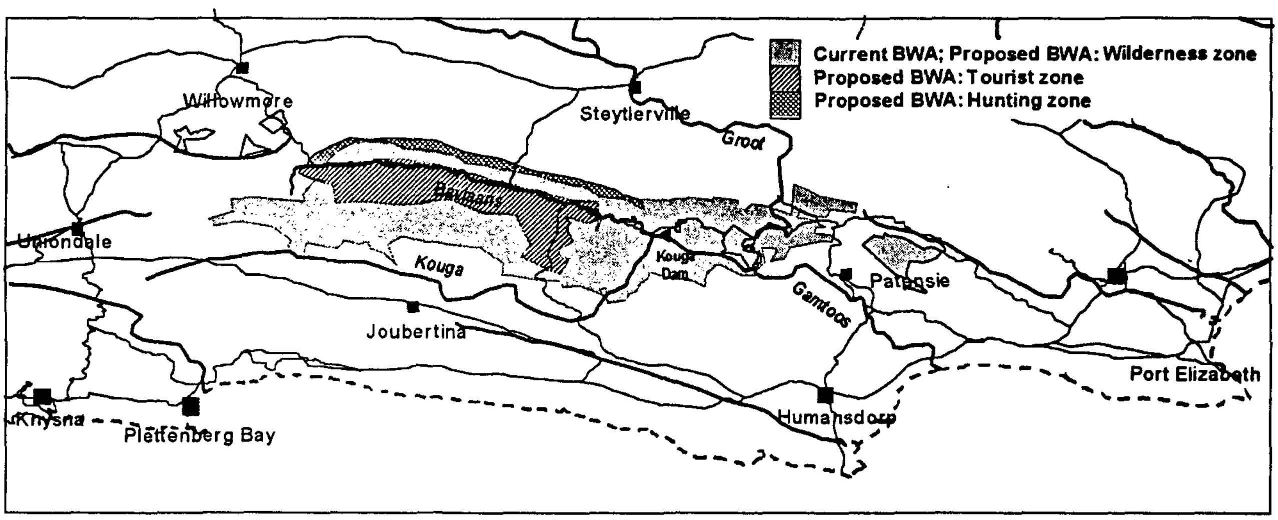


Figure 8.6. Map of the current and proposed expansion of the Baviaanskloof Wilderness Area.

8.2.1 Working Committee Process: SBPP/MCDA

As part of providing general support for decisions regarding the future of the Baviaanskloof Wilderness Area and surrounding areas, a process was envisaged whereby a working committee would be formed to evaluate different alternatives and their impacts using SBPP/MCDA (as in Chapter 3). Representatives from different groups affected by the proposal would provide input regarding alternative visions for the area, the preferences of, and impacts on, different groups, while specialists would provide input regarding likely impacts of alternatives (in particular regarding hydrological, ecological, and social implications). The economics part of the feasibility study would provide the relevant economic information. Only two meetings were held as part of this process; a general public meeting (13 March 1999) and a working committee meeting (10 April 1999) as changes in budget meant that the envisaged series of meetings could not be held.

The first public meeting highlighted the initial concerns (included in Table 8.3) of the Kloof community, and began the process of forming the working committee. The working committee meeting had representatives of: Landowners, Labour, Unemployed, Pensioners, Churches, ECNC, Service providers. Potential landowners aiming to buy a farm in the Kloof chose not to participate. The aims of the working committee meeting were to establish the criteria by which alternatives could be evaluated (which would reflect a broad range of views), and to formulate new alternatives based on the residents' visions for the Kloof.

8.2.2 Scenarios

The status quo, consisting of agriculture, the present BWA and small scale private tourism initiatives (**Scenario 1**) was compared with the BWA proposal (**Scenario 2**) and with a farmer-initiated and run conservancy (Scenario 3) as proposed by a Baviaanskloof Private Nature Reserve Association representative on the working committee. A further alternative was also considered: the status quo with increased tourist facilities and an intensification of tourism within the borders of the current BWA (**Scenario 4**). Due to the termination of the study, further alternatives, in particular those arising from previously disadvantaged sectors could not be developed or explored. Optimistic and pessimistic futures were considered for Scenarios 1 to 3 during the working committee meeting, as well as "critical uncertainties and trends" (see Section 3.2.1). The working committee considered actions and interventions which could change the pessimistic futures. It was envisaged that these actions could later be formulated into new creative scenarios.

Scenario 1: Status quo
Farmers' future choices remain in their own hands. This may include private tourism initiatives within the present set-up. No specific actions would be required to continue in the status quo.

a) **Pessimistic future**. The Kloof will continue to become depopulated, and services will continue to deteriorate, schools would close, and medical services be even more unsatisfactory. Unemployment and housing problems in Willowmore will continue to escalate. The church will lose more of its congregation and income and more assets will lose value. There will be conflicts over water - farmers will want to use more to achieve their aims, but they won't be allowed to under the new Water Act. A dam will inevitably be needed which will be expensive for the state and spoil the wilderness character of BWA. ECNC will not become financially independent so without increasing its tourism revenues in the Baviaanskloof. People will have to leave, but will leave without positive opportunities in Willowmore and so Willowmore will also continue to deteriorate.
b) **Optimistic future**. Farmers envisage continuing to farm, and getting closer to achieving their goals for their farms, including paying off much of their debts. As a result, production and employment will increase, and be more than what ECNC can offer. The new Water Act and labour laws will not unduly affect the viability of their farms (and not more so than if they have to move to farm elsewhere) or their ability to employ more people. Therefore there will be more work opportunities. The broader economic impact of farming in the Kloof will increase, the uniqueness of the area for seed production will be utilised. People staying on farms will continue to get other benefits (like food) which they won't get if they have to move to town.

Scenario 2: Eastern Cape Nature Conservation (ECNC) proposal
A consolidated and expanded Baviaanskloof Wilderness Area (BWA) would be established under the management of ECNC. Tourism developments within the BWA to be privatised once established and housing to be provided for those displaced. The actions required would be to buy farms from the present owners, move residents to Willowmore and provide alternative housing.

c) **Pessimistic future**. There won't be as much tourism as forecast, and so the expanded BWA won't make much money, nor will the surrounding communities and Willowmore. There won't be enough new employment to make a difference to the community or to Willowmore. There won't be enough money to realise housing and training benefits, or to make BWA self-supporting.

d) **Optimistic future**. BWA will be a viable entity and self-sustaining, and services, housing etc. will be improved without draining govt. coffers. People moved from the Kloof will have the opportunity to acquire housing, training and employment through this initiative. Willowmore will be a "gateway" to a tourist area and the area will experience a positive economic trend. Tourism operations within the park will be privatised, thus increasing employment and economic growth. The money saved on not having to build a dam so soon, and on not needing to service the Kloof community, can be spent on other services to the areas or community. Direct and indirect work opportunities generated will be far more than those of farming. Water savings will be realised, creating opportunities for downstream economic activities and postponing the need for a dam.

Scenario 3: Baviaanskloof Private Nature Reserve Owners Association (BPNR) proposal (written submission after meeting)

Farmers would retain land ownership and decision-making powers. Tourism would be promoted though private initiatives, with the cessation of some crop- and stock-farming activities. Some fences might be removed, allowing game to move more freely, but this would depend on whether landowners co-operated through a united decision-making forum. Tourist activities and game utilisation would be managed by individual farmers or by the conservancy as a whole. Farmers would provide bed and breakfast or self-catering accommodation on their farms. The specific actions envisaged would be that farmers would receive a once off payment for stopping production on certain lands, as well as a yearly rental for the land per hectare and wild Large Stock Unit, and government funding would be provided for housing, training, upgrading of workers' houses, land rehabilitation, removal of infrastructure etc.

e) **Pessimistic future** Capital outlay will be too high for both ECNC and individual farmers. Not all farmers will want to or be able to participate and development will therefore be *ad hoc*, and benefits to the community and conservation will not be realised. Developments may be as damaging, if not worse, to the wilderness character of BWA and in terms of water use, as is the status quo. Tourist initiatives will be exclusive and expensive, limiting access for the general population. There will be no labour creation, and the degradation trend in the Kloof and Willowmore will continue.

f) **Optimistic future**. Many people will be employed, and there will be local involvement and empowerment. Economic growth and conservation benefits will be realised through private initiatives. Farmers and workers can continue in the Kloof, and thus the community will be kept together and in the homes where they have grown up and feel they belong.

8.2.3 Criteria

The working committee were asked to consider what issues or criteria they would use in order to evaluate the different proposals or alternatives. These issues are added to those in Table 8.3 which were generated from the public meeting. These would need further refinement and definition in order to be used in an evaluation exercise, but most of them have been included in some form.

8.2.4 Evaluation of scenarios

The underlying assumptions and rationale for the evaluation of the scenarios are included in Appendix 8.2. Effects on employment and remuneration, gross income, social issues, water, and conservation value and management were considered. The costs and benefits are summarised in Table 8.4 on an ordinal scale for each criterion. Rank 1 is the most preferred or most favoured, while rank 4 is the least preferred for the criterion in question. The rank orders were given by the authors based on available information, the discussion in Appendix 8.2 and comments by the working committee. The ranks are, furthermore, based on:

- a generally 'pessimistic' view of the future of the Kloof community under a continuation of the status quo,
- a generally 'optimistic' view about the likely levels of tourism to a new expanded BWA,

- the view expressed that the 'wilderness' and 'conservation' status of the present BWA would be seriously compromised by further development within its borders.

The validity of these views, and the 'probability' of their being true could not be further examined. Furthermore, the fact that alternatives other than expansion of the BWA and a vague 'conservancy' idea were not explored, seriously limits this study. Given these assumptions and limitations, the rank orders provide a starting point for discussion and further study, rather than a conclusion. As the information is ordinal only, and there is no between-criteria information, no overall preferred option can be determined. However, the key role of the criterion 'Disruption and choice' become clear, and together with the assumptions mentioned above, points to the areas which any future studies or decision-making processes should examine more closely, and suggests creatively exploring new scenarios.

Table 8.3 Criteria for evaluation of alternatives, with associated affected groups and issues of concern. SP=Service providers, Loc=Local, Reg=Regional, Nat=National, Int=International

Main criteria group	Sub-Criteria	Affected Groups	Related issues of concern
Conservation & Water	Water use and availability	ECNC, DWAF, SP	Wilderness character, river and associated ecology. Future water supply to Port Elizabeth etc.
	Conservation	ECNC, Nat, Int	Wilderness character, general ecology, aliens. Unique area, ecotone of five zones etc. Ecotoursism. Biodiversity.
	Sustainability of conservation	ECNC	Need to be self-sustaining
	Aesthetics	All	The beauty of the area should not be destroyed through ad hoc developments
Economic	Economic growth	Loc+Reg	Income to Kloof and Willowmore, income to region.
	Sustainability of growth: agriculture, tourism etc.	All	Short or long term gains?
Social	Ability for people to make a living / survive / choose / landownership	All	People want to be able to choose how they live and support themselves. People want the opportunity to own their own land. People are dependent on the decisions of others about how they will live and work. No work opportunities in Kloof or Willowmore at present.
	Quality of services available	All, SP	Improvements particularly in terms or medical, roads and schools are urgently needed in the Kloof.
	Disruption of community	All	There is strong sense of community in the Kloof, which will be destroyed, leading to social problems if people have to move. People don't want to leave because they have lived in the Kloof for years or generations, are happy and have many needs meet in the Kloof. But people are still leaving (services, jobs) and this further worsens the situation in the Kloof. Young people are leaving, have social problems, are demotivated: their voices regarding the future are not heard.
	Housing	All, SP	Some people have inadequate housing arrangements (sanitation, electricity)
	Empowerment and training	All	There are low levels of education, training and opportunities in the Kloof, and people are dependent on the decisions of others regarding their futures.
	Job creation	All, SP	This is of primary importance. There are few job opportunities in either the Kloof or Willowmore.
	Schools	All, SP	The schools are shrinking, teachers are being retrenched and are unmotivated. Schools do not go to secondary level, children have to go to Willowmore – expensive.
	Quality of life	All	The sense of community and other intangibles offered by living in the Kloof are not available in the towns, but towns offer better services.
Other	Ability to accommodate everyone (solution that caters for everyone in some way)	All	It would be unfair to satisfy the needs of some groups through sacrificing those of other groups. There is a need for a solution which is fair
	Practicality	SP, Govt	Solutions need to be realisable in terms of available funding etc.

Table 8.4. Summary of comparison of scenarios on an ordinal scale. Please note: these cannot be added.

	Employ-ment	Remu-neration	**Disruption & Choice**	Services	Gross Income	Conser-vation	Water	Potential to secure funding
Scen 1: Status Quo	4	3	1	2	4	2 or 3	2	2 or 3
Scen 2: BWA proposal	1	1	4	1	1	1	1	1
Scen 3: BPNR proposal	3	3	1 or 2	2	3	2 or 3	2	2
Scen 4: Intensify current BWA	2	2	1	2	2	2	2	2 or 3

8.2.5 Discussion

One of the most important 'lessons learnt' through this study was the importance of having enough time for people to grow comfortable with the approach, and to formulate their own alternatives. Rather than trying to work in a group representing all interests from the beginning it would have been better, in this case, to work with the interest groups separately, at least for the first meeting. This would have helped to gain their trust, and also to enable groups to familiarise themselves with the process, in a situation where they would not have to be adopting 'positions'

Acknowledgements
Part of this study was funded by Vodacom and Telkom.

Appendix 8.1. Scenario descriptions, consequences and scores for Maclear forestry case study

Some of the figures used with regards to hectares owned and afforested were slightly out of date by the time of the fourth workshop. NECF has a total of about 80 000 ha in the Maclear and Elliot districts, about 38 000 ha of which is afforested. They may acquire a further 7 000 ha, and envisage a possible further 5 000 ha from 'external growers' in the district. If all these were acquired the total area would be about 50 000 ha. The range of hectares afforested is thus 38 000 ha to 50 000 ha, as opposed to the range covered here (35 000 ha to 53 000 ha). For this reason, scenarios 2 and 3 were not evaluated in the workshop, but are included for completeness. Scenarios 4a, 5a, 6a were added at the fourth workshop, and certain details are therefore not included. A possible further 15 000 ha may be utilised from existing growers in the Transkei.

Scenario 1. Status quo, afforestation remains at approximately present levels into the future. In approximately 2014, the first harvest would occur for sawmilling. The number of hectares owned are approximately 64 000, and afforested hectares are 35 000. Sufficient lumber should be available for the operation of a sawmill with an output of about 200 000 m^3/a as well as a smaller one with an output of about 64 000 m^3/a.
Scenario 2. As for Scenario 1, but existing options are taken up, and afforested, bringing the total afforestation to about 44 000 ha. Two sawmills with a total output of about 330 000 m^3/a could be supported.
Scenario 3. As for Scenario 2, but further farms would be acquired to consolidate present operations (for example to improve fire control and access). Total afforestation would be approximately 50 000 ha, supporting sawmills with a combined output of about 370 000m^3/a.
Scenario 4. As for Scenario 3, but options & desired farms in the Elandsheights area would be acquired (mainly landtypes 1 & 2), bringing the total afforestation to about 53 000 ha, to support sawmills with a combined output of about 400 000 m^3/a. **Scenario 4a.** As for Scenario 4, but none of the new afforestation would occur on landtypes 2, 4 and 9.
Scenario 5. As for Scenario 4, but the primary processing would consist of a pulpmill in the Maclear district, with an output of about 300 000 T/a. For this scenario, 90 000 T of input would have to be augmented from external sources (e.g. chips). **Scenario 5a.** As for Scenario 5, but none of the new afforestation would occur on landtypes 2, 4 and 9.
Scenario 6. As for Scenario 5, but the primary processing would consist of a pulpmill *not* in the Maclear district, with an output of ~ 300 000T/a. For this scenario, 90 000 T of input would have to be augmented from external sources (e.g. chips). **Scenario 6a.** As for Scenario 6, but none of the new afforestation would occur on landtypes 2, 4 and 9.

The **Sub-scenarios** relating to multiplier effects on employment from different land-uses and processing ranged from 1.2 for all, to a multiplier of 6 for a pulpmill. Only sub-scenario 1 (1.2 for all) was used in the end:

- **Sub-scenario one (local):** Multiplier effects of 1.2 are included for agriculture, plantations, sawmills and the pulp-mill in Scenario 5 (in Maclear). Scenario 6 has a multiplier of 1 at the local level (i.e. none).

Table 8.1. Scenarios and data relating to agriculture. Data marked with * are based on StatsSA 1988 agricultural census. Percentages of agricultural production are made by extrapolating assuming that % of land-use in different forms of agriculture remain at 1988 levels

			Cattle	Maize	Wheat	Potatoes
1988	% of provincial production (in quantity) *		7	27	3	17
	Gross income R/ha *		124	798	343	5161
	Agriculture land ha	Farm land lost ha	% of provincial production (in quantity) *			
Scenario 1	157514		5	20	2	12
Scenario 2	141902	15612	5	17	2	11
Scenario 3	130766	26748	4	16	2	10
Scenario 4	124689	32825	4	15	2	9
Scenario 5	124689	32825	4	15	2	9
Scenario 6	124689	32825	4	15	2	9

'Table 8.2 (and Figure) NPV from agriculture. No primary processing is included. Most of this NPV would be accruing to the local area. The second graph is rescaled for comparison to the Figures for plantations.

	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
6%	97846196	87780896	80601988	76684052	76684052	76684052
3%	133283485	119572802	109793884	104456975	104456975	104456975
9%	75183859	67449802	61933614	58923118	58923118	5892118

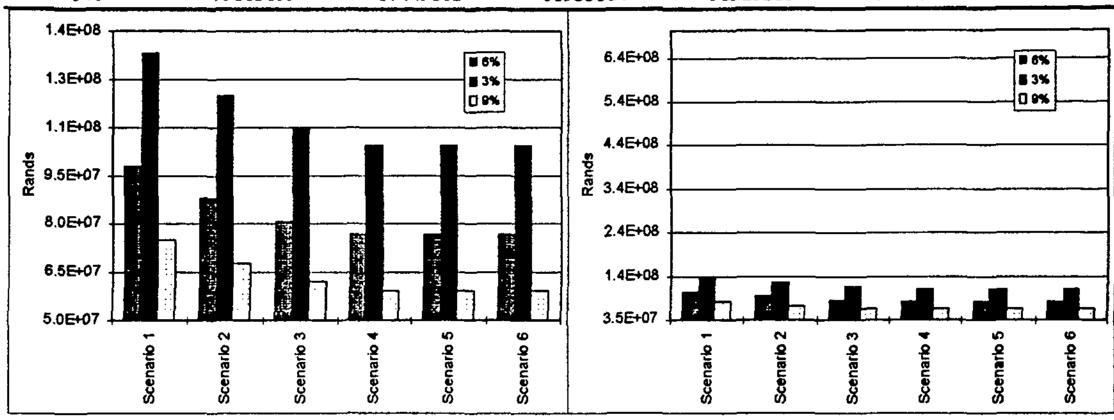


Table 8.3 (and Figure) NPV from plantation sales and primary processing of forestry products at three discount rates. These figures show likely amounts accruing to the local area. About 68 % of sawmill and about 20 % of pulp-mill spending may occur at the local level. (Second graph is rescaled for comparison to the plantation figure)

Discount Rate	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
6%	78980988	98088943	111811672	119299241	194042622	148081761
3%	149966717	186257616	212315218	226533097	323280483	247999728
9%	41790951	51897338	59157821	63119377	119048078	90192210

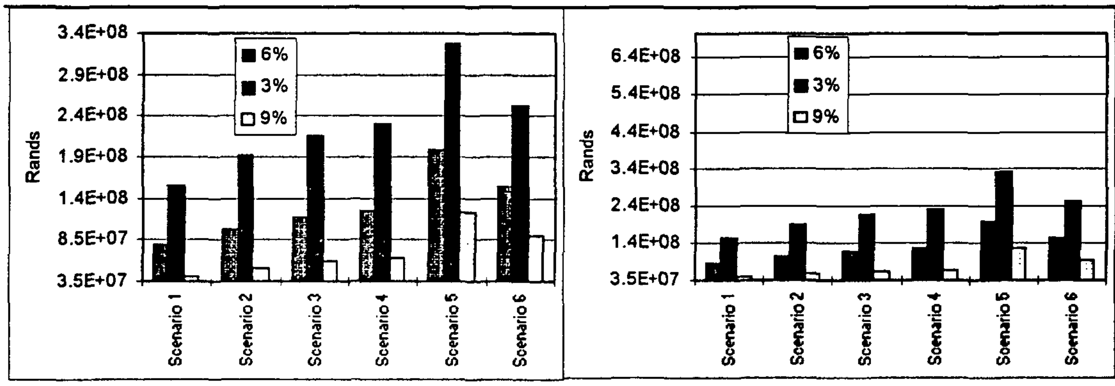


Table 8.4 (and Figure) NPV from plantation sales and primary processing of forestry products at three discount rates. These figures are unadjusted for 'local' or other effects.

Discount Rate	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
6%	91089655	113133937	128961474	137597494	394339593	394339593
3%	172767917	214588809	244609970	260990496	651959027	651959027
9%	48282854	59963181	68352082	72929340	244492910	244492910

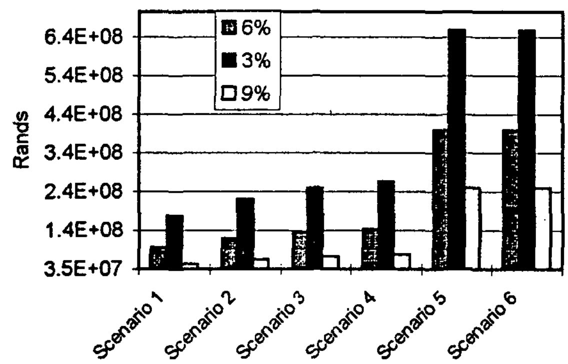


Figure. Number of people employed under various multiplier 'Sub-scenarios'. Numbers are those who will be employed in 2015 (i.e. *after* either a sawmill or pulp-mill has been built).

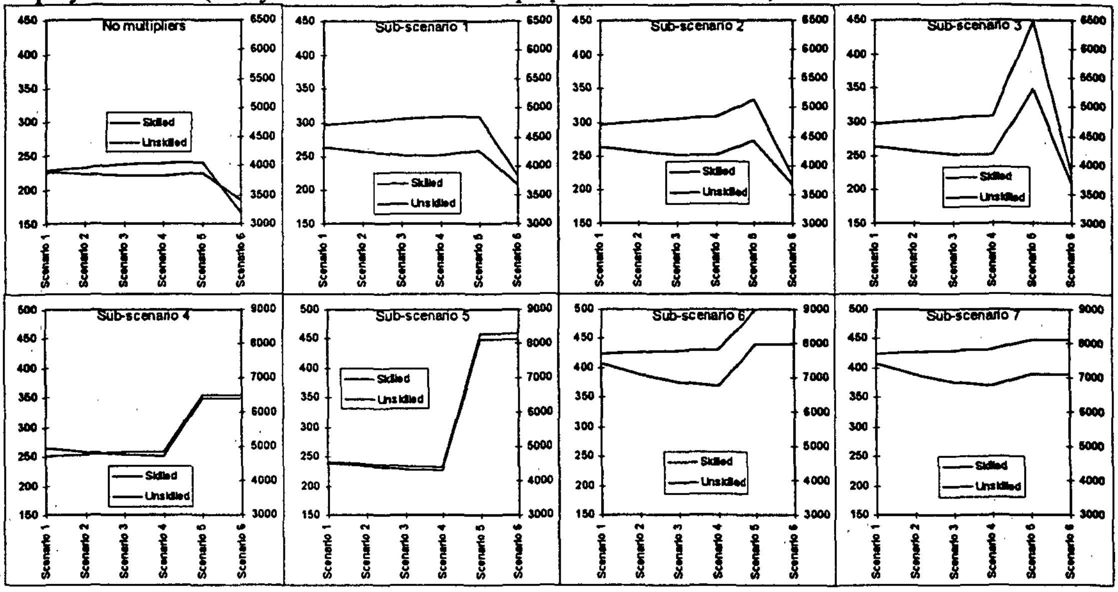
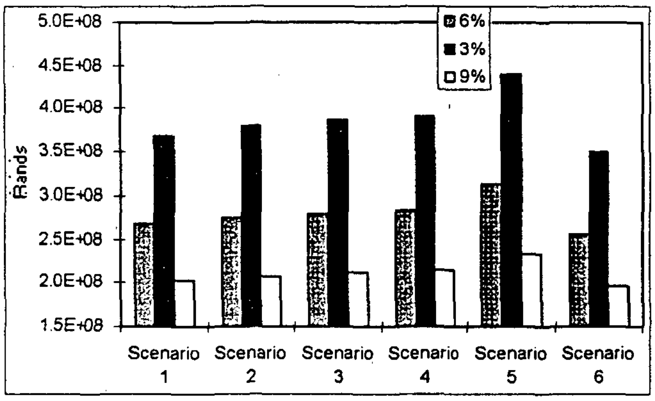
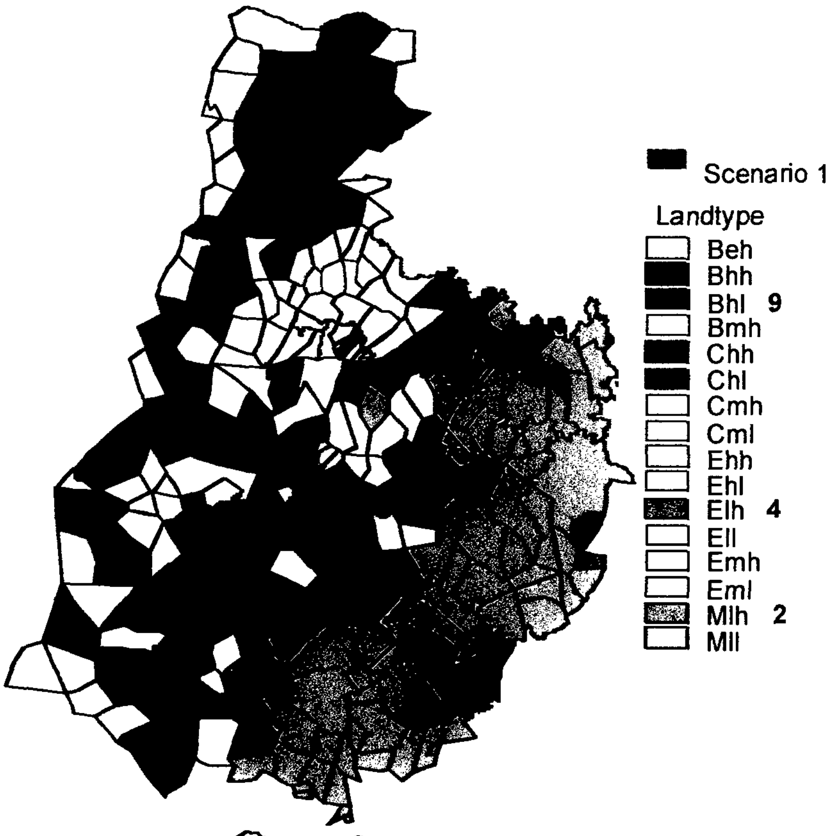


Table 8.5 (and Figure) NPV of income from employment in the region. Only Income without multiplier effects is shown. This relates to the first of the graphs in the Figure.

Discount Rate	Scenario 1	Scenario 2	Scenario 3	Scenario 4	Scenario 5	Scenario 6
6%	2.67E+08	2.74E+08	2.80E+08	2.83E+08	3.12E+08	2.56E+08
3%	3.69E+08	3.8E+08	3.9E+08	3.9E+08	4.39E+08	3.5E+08
9%	2.03E+08	2.08E+08	2.1E+08	2.1E+08	2.33E+08	1.96E+08





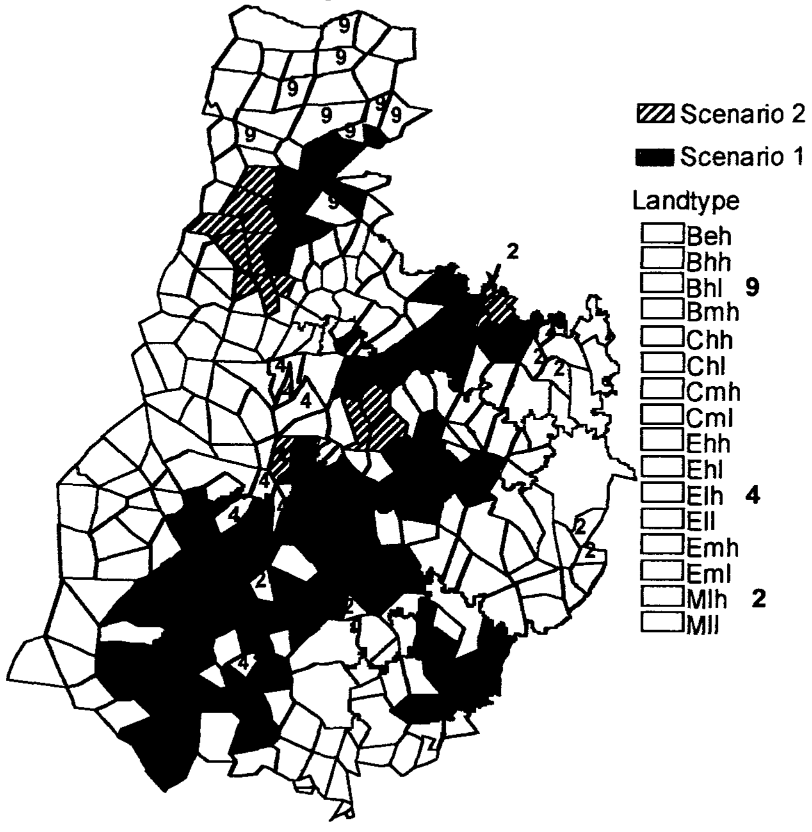
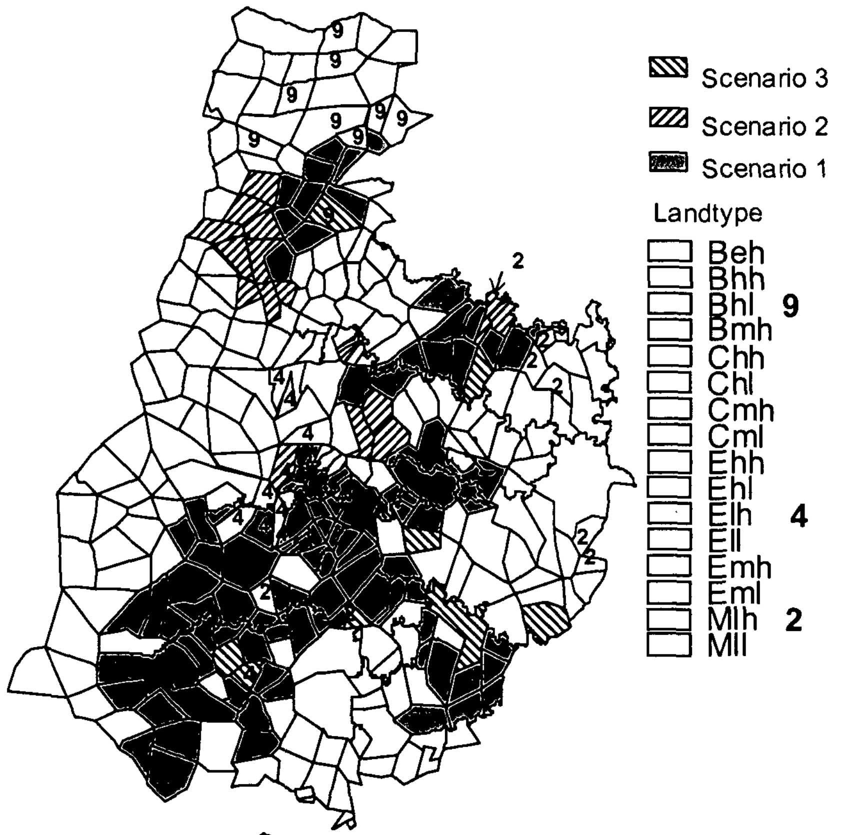


Figure A8.1-1. Map showing the status quo - Scenario 1, with the dark green shaded areas showing the presently afforested farms. Mlh is land-type 2, Elh is land type 4, and Bhl is land type 9.

Figure A8.1-2. Map showing Scenario 2 (hatched shading). Dark areas are presently afforested (Scenario 1). Mlh is land-type 2, Elh is land type 4, and Bhl is land type 9 as per Figure A8.1-1.



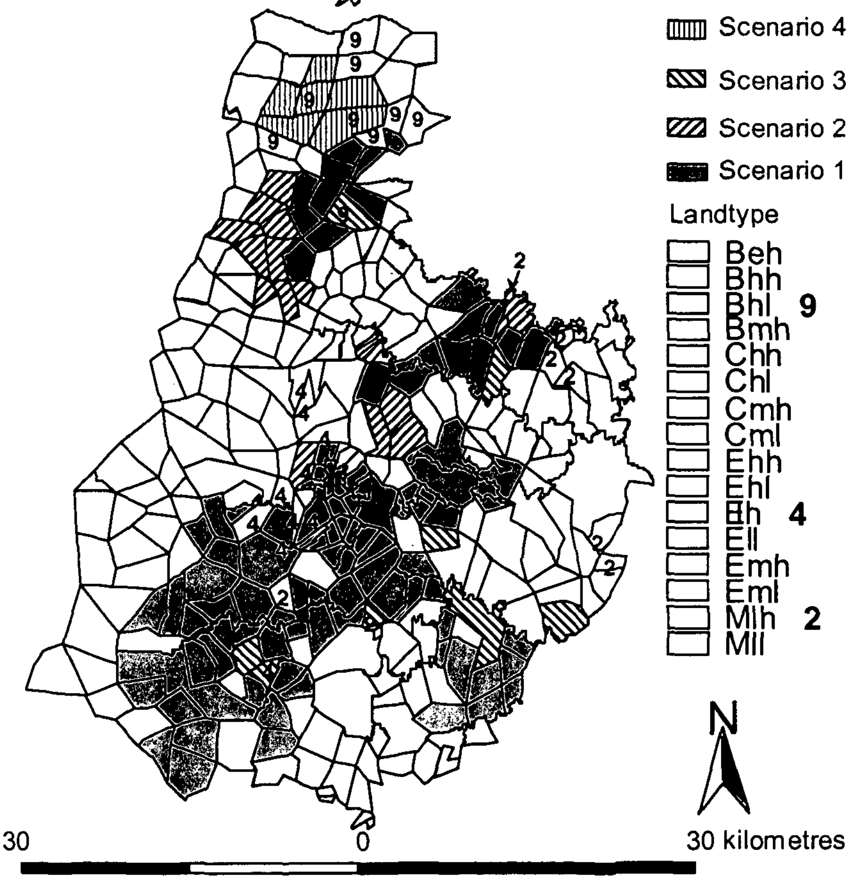


Figure A8.1-3. Scenario 3: Dark areas are presently afforested (Scenario 1). Mlh is land-type 2, Elh is land type 4, and Bhl is land type 9, as per Figure A8.1-1.

Figure A8.1-4. Scenario 4: Scenarios 4a, 5a, 6a have the same area of afforestation as Scenario 4, but none on land-types 2, 4, and 9.

Multipliers and Secondary industries

A multiplier effect may be expressed in Rand terms as an economic multiplier or in numbers employed as an employment multiplier. These may be determined through input/output tables (obtainable from StatsSA) which give production for various sectors of the economy. Forestry, agriculture, fishing and hunting are regarded as the same sector for the purposes of these tables, and so no differentiation between these is possible without extensive analysis of data which was not available to us. Various economists gave their opinions on multipliers (e.g. A. Leiman, University of Cape Town, J. Turpie, University of Cape Town, R. Hassan, University of Pretoria), and felt that there was no *a priori* reason to expect the multiplier effects from the saw and pulp-milling industries to be substantially different from that from the processing of any agricultural products. The range of economic multipliers on a local level was suggested to be from 1.2 to 1.8 for any sector including agriculture and forestry. The range of economic multipliers on a national scale for any sector including pulp-mills which involved processing, transport and packaging, was variously suggested as from 2 to 5, (J. Turpie & A Leiman, pers comm. and Hassan, 1997) and 14 for pulp-mills where linkages to timber supply are included (cited in Hassan, 1997). As the determination of more precise values specific to the decision context was beyond the scope of this study, a realistic range of multiplier effects was included in various "sub-scenarios". The participants decided that Subscenarios 1 and 2 covered a reasonable range of multiplier effects (only the Sub-scenario 1 is presented here). The meso-scale of decision-making meant that multiplier impacts on GDP or other national level indicators was inappropriate and so the multiplier impact on employment and personal income in the region were the criteria considered.

Social issues

Numbers of people employed in agriculture were based on Central Statistical Services agricultural survey for 1988 (StatsSA, 1988), and some interviews with farmers, giving an average number of hectares per employee as 60. Numbers employed in primary processing in agriculture were not available. Numbers employed in forestry (plantations) were based on NECF's own employment figures. At employment of 500 plus 300 contract workers this gives the number of hectares per employee as 80. The number of *planted* hectares per employee is around 40, but this figure is not used as the entire forestry owned area is not available for other activities. Numbers employed in primary processing of forestry were determined through interviews and questionnaires with similar processing plants around the country. However, the sample size was small (3 sawmills and 1 pulp-mill).

Employment figures in general are likely to change over the 25 year period included in the analysis. Estimates are that a fairly large, high tech saw- or pulp-mill, will employ only 50 people in the future, as seen in countries such as Canada and Sweden. In agriculture, the trend seems to be away from extensive land-use (where the employment rate is low) towards more intensive land use (crops such as maize and horticultural products such as potatoes) where the employment rate is higher. However, there is a parallel trend to more mechanised agriculture. Not much of the Maclear district is arable, so the change in either direction may be fairly small and therefore irrelevant. We have for the purposes of this analysis kept employment figures for agriculture, plantations, saw- and pulp-mills at the equivalent of 1995/1996 levels.

Remuneration was kept at constant 1995/1996 wages and discounted at 6 % over the 25 year period of the analysis with 3 % and 9 % discount rates included for sensitivity. Figures were obtained from StatsSA (1988), interviews with farmers, saw- and pulp-mills and from NECF employment records. StatSA data included "payment in kind", such as rations, use of land or free rental. However, updated information was not available except from a small sample of farmers, and this kind of payment was largely unspecified. Agricultural pay may therefore be underestimated.

The criteria relating to housing and services and personal well-being were assessed directly at the workshops. The former referred to the case of access to housing and services such as schools and clinics (electricity and water services being addressed in the criteria infrastructural development). The latter, perhaps unfortunately named, referred to aspects such as diversity of employment opportunities, capacity building, security of tenure, stakeholdership. Originally it also included issues such as social disruption (as for example, farm workers are moved from the farms to the towns when farms are bought up by forestry), but this was later not explicitly addressed.

Economic impacts on Maclear district

The term NPV is usually associated with an "economic" analysis, but in this case refers to a "financial" analysis. An economic analysis would include externalities such as social and environmental impacts, the effects of subsidies, price controls and exchange rates etc. In our example, at least some of these, are explicitly included in the other criteria considered, specifically the environmental, social and agricultural issues. We see this as one of the advantages of MCDA, in that, these aspects are often totally ignored or only mentioned as parallel information (rather than included in the actual analysis). This is largely due to the fact that determining the monetary value of environmental effects is difficult and controversial (e.g. Joubert *et al.*, 1997). All calculations of net present value (NPV) were based on a 25 year period, starting in 1997 and ending in 2021 at a discount rate of 6%. This period included the building of a primary processing plant for forestry and some years of harvesting and processing. A longer time period could have been used but the essential trends seem to be captured over this time. A large proportion of this time excludes income from harvesting, as these have not completed their first rotation (taken as 25 years for sawlogs, and 18 years for pulpwood). This should not be perceived as a problem as the long lead-in time of forestry is a very real characteristic, and to ignore this would be to seriously bias the results. A discount rate of 6% (generally accepted as the present real interest rate), was applied over the period to give NPV. To assess sensitivity, 3% and 9% were also used, the former essentially implying that later impacts have higher importance, and the latter meaning that immediate gains are more important than future gains. In some cases information was readily available in some detail, while in other cases, key aspects were missing. In general, costs reported in the available literature, included running costs, interest repayments, maintenance, overheads etc. but capital costs were not specified. As this was a common thread through all the economic information it was decided to use the "net cash flow from operations" rather than the true net income. This would have fairly serious implications for the pulp-mill industry where capital costs are large. The exact NPV calculation depended on the available information.

NPV of Forestry

Income from plantations was calculated using the Forestry Economic Services data for 1995 (FES, 1995), but MAI and rotation length were taken as 25 year (sawmill) or 18 years (pulp-mill) based on G. Botha (pers. comm.). From these figures, the total m^3 produced for each scenario could be calculated. Until the first harvest, only costs are reflected (a slightly unrealistic view as a new project would presumably be cross-subsidised by other well established projects). At the time of the first harvest, and for the remaining years, the 1995 prices for standing timber sold for sawing or for pulping were used to calculate income. A questionnaire sent to various saw- and pulp-mills in South Africa asked for a breakdown of their sales Rand. The breakdowns included costs of interest repayments and depreciation, costs of timber and non-timber input, and percentage profits (3% for saw-mills, 11 % for pulp-mills). The volume of output was multiplied by 1995 prices for pulp or sawn timber and multiplied by percentage profit to give net income. The crude approach and small sample size does cast some doubt on the accuracy of the results, but it was reasonable to assume that the general trends shown would not change with more accurate data, and that the results were at least within the right order of magnitude. New information available from after the fourth workshop indicated that sawmills may in fact be relatively more profitable than pulp-mills. For example, a survey of saw and pulp-mills in British Columbia, Canada, gave average percentage profits at 11 % and 9 % respectively (as compared to 3 % and 11 % from the South African questionnaire respondents), implying a rather large underestimate of returns from saw-milling in the calculations presented here. As the impacts of concern are those felt in the Maclear district, the NPV calculations were adjusted to reflect the percentage of NPV spent within the area, as far as this could be determined from the sales Rand breakdown. This was determined as 68 % and 20 % for saw- and pulp-mills respectively.

NPV of Agriculture

All agricultural calculations were based on the 1988 agricultural census (StatSA, 1988) to obtain production per hectare, and the Agricultural Abstract for 1995 to obtain prices. The percentages of land being used for various forms of agriculture were calculated and these percentages were assumed to remain constant. For each scenario, the non-forestry land was apportioned to these land-uses. The amounts of beef and dairy products, maize, wheat and potatoes produced were determined based on the production per hectare from the 1988 census and multiplied by 1995 prices to give gross income. The net income for the district was determined for 1988 and expressed as a percentage of gross income, and gross income for each scenario was multiplied by this percentage. A larger percentage of this NPV will accrue to the Maclear district than in the case of saw-mills, but no adjustment was made to the percent as this information was not available.

"Tourism" and "Development of infrastructure"

Both of these criteria were given direct scores based on direct judgement of the available information by the workshop participants as a group.

Economic criteria

Agriculture

Criterion	NPV of agricultural production (1997-2021) Criterion level ($Rx10^6$)	Value (score)	Viability of small farms Value (score)	Local food production Value (score)
Scene 1	98	**100**	**100**	**100**
Scene 2	88	**57**	**?**	**?**
Scene 3	81	**26**	**?**	**?**
Scene 4	77	**9**	**6**	**6**
Scene 5	77	**9**	**6**	**6**
Scene 6	77	**9**	**6**	**6**
Scen 4a	75*	**0**	**0+**	**0***
Scen 5a	75*	**0**	**0+**	**0***
Scen 6a	75*	**0**	**0+**	**0***
Weight	*0.754*		*0.124*	**0.122**

* Not actually determined, but assumed that some more profitable (arable) land may be used for forestry if forestry constrained not to be on land-types 2, 4 and 9.
+ Similar assumption to *.

Forestry

Criterion	NPV of plantation and primary processing (1997-2021) Criterion level ($Rx10^6$)	Value (score)
Scene 1	79	**0**
Scene 2	98	**17**
Scene 3	111	**28**
Scene 4	119	**35**
Scene 5	194	**100**
Scene 6	148	**60**
Scen 4a	115+	**31+**
Scen 5a	178+	**86+**
Scen 6a	132+	**46+**

+ A calculation made after the fourth workshop, which assumes that the MAI, on 5000 ha is reduced from 15 to 10 m^3/ha/a, as forestry is constrained not to be on land-types 2, 4, and 9. This means that forestry *may* go to land which is less favourable and MAI *may* consequently be reduced. These values are used in all other analyses.

Tourism Potential & Regional Development

Criterion	Tourism Potential Value (score)	Development of infrastructure Value (score)
Scene 1	**100**	**25**
Scene 2	**?**	**?**
Scene 3	**?**	**?**
Scene 4	**65**	**30**
Scene 5	**0**	**100**
Scene 6	**10**	**0**
Scen 4a	**80**	**30**
Scen 5a	**15**	**100**
Scen 6a	**25**	**0**

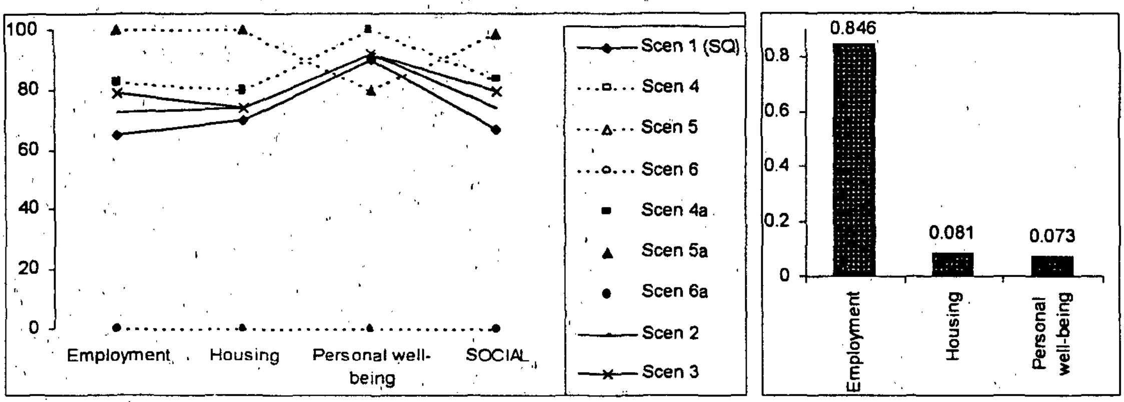
Social criteria

Criterion	Employment numbers in 2021 Criterion level (#)	Employment numbers in 2021 Value (score)	Remuneration (NPV 1997-2021) Criterion level (Rx10^6)	Remuneration (NPV 1997-2021) Value (score)	Housing and services Value (score)	Personal well-being Value (score)
Scene 1	4974	**86**	267	**20**	**70**	**90**
Scene 2	5034	**92**	274	**32**	**?**	**?**
Scene 3	5082	**96**	280	**43**	**?**	**?**
Scene 4	5109	**99**	283	**48**	**80**	**100**
Scene 5	5123	**100**	312	**100**	**100**	**80**
Scene 6	4043	**0**	256	**0**	**0**	**0**
Scen 4a	5109	**99**	283	**48**	**80***	**100+**
Scen 5a	5123	**100**	312	**100**	**100***	**80**
Scen 6a	4043	**0**	256	**0**	**0**	**0**
Weight	*0.677*[#]		*0.323*[#]			
Weight	*0.846*				*0.081*	*0.073*

* It is assumed that the mills create extra housing and services to more than compensate for losses through displacement from farms taken over for forestry.

\+ Saw mill has greater potential for local training, and wood is more obviously a benefit locally than pulp. Pulp mill will also create benefits through training, but will be more likely to use trained people from outside the area.

[#]The scores for numbers employed and remuneration are summed with these weights to give an overall 'employment' score.



Value profiles and weights associated with social criteria.

Environmental issues

Conservation Criteria

The criteria considered within the category "conservation" were the number of land-types (as identified in Armstrong and van Hensbergen, 1997) which could be considered conserved in the district, the total untransformed area, contiguity of untransformed areas and general degradation of the area. Individual farms were classified as one of 16 land-types, but only the ten sampled in Armstrong and van Hensbergen (1997) were included. In the different scenarios, these farms were designated as either belonging to forestry or agricultural. Those remaining in agriculture could be summed for each scenario, to give the number of land-types preserved, which could be adjusted to only include farms larger than a certain area. Similarly, the total untransformed area was calculated and this was adjusted by the percentage of area which was used for crop farming, based on Forsyth *et al.*'s (1996) assessment of the areas of crop farming in quaternary catchments of the district based on Landsat imagery. Maps were supplied by NECF which showed the exact location of their plantation blocks in the district and contiguity was assessed qualitatively by the conservation representatives (van Hensbergen and Armstrong) by referring to these maps. Degradation was a composite qualitative rating which included such aspects as the likelihood of dispersion of aliens, soil erosion etc.

Criterion	Number of land-types preserved Value (score)	Untransformed area Value (score)	Contiguity Value (score)	Degradation Value (score)
Scene 1	100	100	100	100
Scene 2	?	?	?	?
Scene 3	?	?	?	?
Scene 4	5	0	0	10
Scene 5	0	0	0	10
Scene 6	0	0	0	10
Scen 4a	85	9	25	0
Scen 5a	80	9	25	0
Scen 6a	80	9	25	0
Weights	*0.545*	*0.099*	*0.279*	*0.077*

Criterion level for Number of land-types preserved (Frequency of occurrence-types 1-10)										
Land type number	Land type	Scene1	Scene2	Scene3	Scene4	Scene5	Scene6	Scene4a	Scene5a	Scene6a
1*	Mll	72	61	58	58	58	58	Not specifically determined		
2*	Mlh	6	5	4	4	4	4	6	6	6
3	Ell	32	25	18	18	18	18	Not specifically determined		
4*	Elh	9	6	3	3	3	3	9	9	9
5	Eml	11	11	11	11	11	11	Not specifically determined		
6	Emh	15	14	13	13	13	13			
7	Ehh	7	6	6	6	6	6			
8*	Chh	14	14	14	14	14	14			
9*	Bhl	9	9	8	6	6	6	9	9	9
10*	Bhh	19	18	17	14	14	14	Not specifically determined		

Criterion level for Untransformed Area of Land-types 1-10: ha [Percentage]										
Land type number	Land type	Scene1	Scene2	Scene3	Scene4	Scene5	Scene6	Scene4a	Scene5a	Scene6a
1*	Mll	49905 [60.3]	43172 [52.1]	40064 [48.4]	40064 [48.4]	40064 [48.4]	40064 [48.4]	Not specifically determined		
2*	Mlh	2763 [56.2]	2386 [48.5]	2098 [42.7]	2098 [42.7]	2098 [42.7]	2098 [42.7]	2763 [56.2]	2763 [56.2]	2763 [56.2]
3	Ell	17821 [41.9]	14409 [33.9]	10795 [25.4]	10795 [25.4]	10795 [25.4]	10795 [25.4]			
4*	Elh	4156 [58.3]	2559 [35.9]	1124 [15.8]	1124 [15.8]	1124 [15.8]	1124 [15.8]	4156 [58.3]	4156 [58.3]	4156 [58.3]
5	Eml	6009 [96]	6009[96]	6009 [96]	6009 [96]	6009 [96]	6009 [96]			
6	Emh	8548 [87.3]	7666 [78.3]	7185 [73.4]	7185 [73.4]	7185 [73.4]	7185 [73.4]			
7	Ehh	3557 [57.1]	2920 [46.8]	2920 [46.8]	2920 [46.8]	2920 [46.8]	2920 [46.8]			
8*	Chh	11217 [95.5]	11217 [95.5]	11217 [95.5]	11217 [95.5]	11217 [95.5]	11217 [95.5]			
9*	Bhl	7800 [70.6]	7800 [70.6]	6961 [63.0]	4560 [41.3]	4560 [41.3]	4560 [41.3]	7800 [70.6]	7800 [70.6]	7800 [70.6]
10*	Bhh	16797 [89.6]	16175 [86.3]	15663 [83.6]	12071 [64.4]	12071 [64.4]	12071 [64.4]			

Hydrology criteria

Hydrology impacts were divided into those affecting quantity and those affecting quality, and were taken to subsume any effects on riverine ecology. Criteria relating to quantity were identified as mean annual runoff (MAR), low flows and peak flows. Water quality included both silt load and chemical load. Water quantity impacts (MAR and low flows) were determined from Forsyth *et al.* (1996), while quality issues were addressed in the workshop by Versfeld and Forsyth. In the context of these catchments, the effects on peak flows were considered to be negligible: the criterion is included for completeness, although a weight of zero was.

Criterion	Reduction in MAR (%)	Reduction in low flows (%)		Silt load	Chemical load
	Value (score)	Criterion level	Value (score)	Value (score)	Value (score)
Scene 1	100	6	100	100	100
Scene 2	?	9	92	?	?
Scene 3	?	11	87	?	?
Scene 4	60	12	85	0	63
Scene 5	0	20	0	0	0
Scene 6	40	12	66	0	66
Scen 4a	60	12	85	0	63
Scen 5a	0	20	0	0	0
Scen 6a	40	12	66	0	66
Weight	*0.662*	*0.338*		*0.338*	*0.662*
Weight	*0.246*			*0.745*	

Appendix 8.2. Background to Baviaanskloof Wilderness Area and consequences of scenarios

A1.1. Background

Present management, conservation status and tourism of the BWA

The BWA, enclosed by the Kouga and Baviaanskloof mountains, stretches through the magisterial districts of Hankey, Humansdorp, Joubertina, Uniondale, Willowmore and Steytlerville. Originally, the BWA was a water catchment area, the Baviaanskloof Forest Reserve, managed by the Dept of Water Affairs and Forestry. In the 1980s it was handed over to Cape Nature Conservation as the BWA and thus became a nature reserve by default and not design. As such, the BWA is not adequately legally protected as a conservation area. Because of the long and convoluted boundary, the management of the area is expensive and the potential conflicts with neighbouring landowners are high (e.g. fire risks, "pest" animals, alien vegetation, soil erosion, water wastage etc.).

The BWA is presently about 180 000ha in size, the size having increased over the years. During the three years prior to 1989, 12 000 ha of private land were bought and included in the BWA (du Preez, 1989). The present BWA is an ecotone of five veld types (Vlok 1989): afromontane forest, sub-tropical thicket (valley Bushveld and Spekboomveld), fynbos (wet, mesic and xeric mountain fynbos and grassy fynbos), Cape transitional (south coast Renosterveld), and Karoo shrublands. The area has a high biodiversity, including 58 mammal species, 293 bird species and 11 fish species, three of which are indigenous. Numerous species are Red Data listed, including leopard (*Panthera pardus*), Cape mountain zebra (*Equus zebra zebra*), and grey rhebok (*Pelea capreolus*). The distribution and occurrences of Red Data plants is poorly known (Clark 1998).

The entire catchments of the two main tributaries of the Gamtoos river, the Kouga and the Baviaanskloof Rivers, are affected by the management of the Kloof and the BWA. Water is contributed by the Kouga and Baviaans Rivers to the Kouga Dam. Irrigation in the Gamtoos Valley, downstream of the present BWA started in 1843. The Kouga Dam was completed in 1964, and has a storage capacity of 128.7 Mm^3 with a surface area of 555 ha. It has been estimated that the Baviaans River supplies 45% of the flow to the Kouga Dam. 7 400 ha of land in the Gamtoos Valley are irrigated from this dam, using a maximum of 8 000 m^3 per ha per year (DWAF, 1992). The Kouga/ Loerie system supplies 23 Mm^3/a to the Port Elizabeth municipality and 58.6 Mm^3/a to the Gamtoos Irrigation Board, which generally use 44 Mm^3/a[11]. The Gamtoos Canal is subject to high losses (around 13.5 Mm^3 per annum). There do not appear to be plans to remedy this. Catchment management agencies will be formed to manage and allocate water resources appropriately within water management areas. The Kouga and Baviaanskloof Rivers fall within management area 15, the major rivers of which are the Fish, Kowie, Boesmans, Sundays, Gamtoos, Kromme, Tsitsikamma and the Groot. In terms of the NWA, the Reserve for basic human needs and the environment, has to be met before any other allocations are made.

A multitude of cultural sites and relics of previous inhabitants and civilisations are represented in the BWA and Kloof. There is evidence of pre-historic man back to between 100 000 and 30 000 years ago (Middle Stone Age), and Khoisan deposits and rock paintings dating back 12 000 years. The archaeological record is well preserved in a number of sites but very little research has been done. Research on plant deposits show natural changes in the environment as well as man-influenced ones dating back to these early times (e.g. Khoi burning of veld). The arrival and influence of Khoisan,

[11] It is worth noting that the perception exists in the Kloof, that the Gamtoos Irrigation Board is using more than their original allocation. This would have to be addressed by an implementation study.

Xhosa, English, and Boer are represented here as well as conflicts between the various groups. The recent finding in the area of a Khoisan body mummified using the gifbol plant, has already had an impact on our understanding of Khoisan culture and herbal knowledge. The more recent history of the BWA, reflected in the intriguing stone walls built by Xhosa inhabitants, in old farm houses and churches, also forms part of the region's cultural heritage and need conserving (Binneman, 1989). *All* cultural artefacts older than 100 years are covered by the National Heritage Resources Act (1999).

The reserve thus features magnificent mountain scenery, plateaux and gorges, high biodiversity and numerous archaeological sites. There presently are five six bed holiday chalets, two 'primitive' camping sites, a serviced camp site with ablution facilities, and three rudimentary dwellings. Past and current visitor numbers are indicated in Figure 8.1. Currently, 75% of visitors stay overnight (approximately 34% occupancy), and activities include hiking, canoeing, fishing and horse riding.

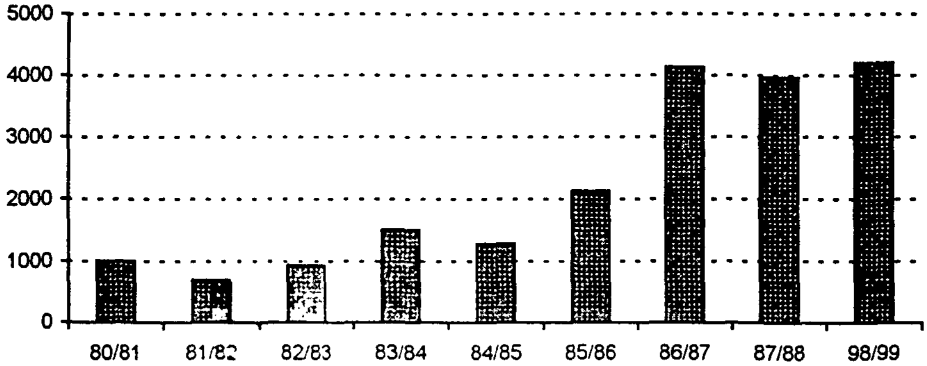


Figure 8.1. Visitor numbers to BWA. Data for 80-88 are from Kerley and Els (1989), and that for 98/99 from D Clark (pers comm).

Regional Context

The Eastern Cape, the country's second largest province, has population density (38.2 persons per km^2), population growth (nearly 3% /a), poverty, life expectancy (60.7 years), unemployment (45.3%), inflation (9.3%), adult literacy (72.3%) and per capita annual income (and R4 151) figures which are poor relative to the national average, and are generally only second to Northern Province (StatsSA, 1996).

The Eastern Cape climate lends itself to outdoor activities and ecotourism as there are over a hundred game and nature reserves offering game and bird watching, fishing, camping, canoeing, hiking and hunting (Myles & Mullins 1993). Despite this, the Eastern Cape is largely under-exploited and tourism in the province is highly seasonal, discouraging high capital input into projects (MLH Architects & Planners, 1998). The BWA proposal aimed to capitalise on this 'gap' in the market, while conservation, economic and living conditions in that part of the province. In addition, Eastern Cape Nature Conservation (ECNC: the Directorate Nature Conservation of the Department of Economic affairs, Environment and Tourism) needed to generate funds so as to be self-financing.

Directly affected communities

The expansion of the BWA would involve the relocation of people from farms in the Baviaanskloof to Willowmore, affecting several different communities. The towns neighbouring the BWA (Willowmore, Uniondale, Joubertina and Patensie) may experience changes in economic activities and /or population. However, the community within the Kloof and the town of Willowmore will be most directly affected, as the proposal would require the moving of approximately 1000 people (about 200 households) from the Kloof to Willowmore. Thus, Willowmore will face an increase in population and requirements for services, and the Kloof community will be uprooted, and require alternative employment and housing in Willowmore.

Farming within the Baviaanskloof (the area referred to as the Kloof) has changed noticeably over the years. The present viability of farms may only be possible because of access to free, unrestricted water, low wages, and non-compliance with agriculture and water resource legislation, although farmer representatives on the working committee felt that this was not entirely true and that these issues were not unique to the Kloof, but generally applicable to farming in South Africa. In contrast, they felt optimistic about future viability. The application of the NWA and minimum wages, together with other labour and agricultural laws may further reduce the viability of these farms. However, the stagnation within the Kloof may also be partly attributable to the loss of agricultural land over the years due to acquisitions by DWAF (for the building of the Kouga dam) and ECNC (for previous consolidation of BWA). In other areas, the need for a 'critical mass' of farmers in order to maintain a viable farming community has also been acknowledged (e.g. Chapter 8). Employment in the agricultural sector in the Willowmore area is steadily declining (Figure 8.2), a trend common to the rest of South Africa. Some decreases are attributable to loss of agricultural land, but the number of employees per 1000 ha shows a 10% drop from 1981 to 1988 and another 10% decrease from 1988 to 1993. Gross income from agriculture hardly changed from 1988 to 1993, and so, taking inflation into account, real income decreased by about 50%.

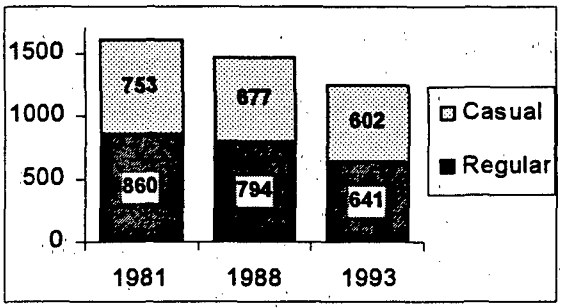


Figure 8.2. Regular and casual employment in agriculture for the Willowmore magisterial district for the last three agricultural censuses (StatsSA, 1981, 1988, 1993).

A socio-economic survey (Kruger 1997) showed that 1348 people (239 households / families with an average of 5.64 persons) were living in Baviaanskloof. There were four schools, four postal agencies, five churches, a church community with a community hall, six farm shops and a police station. Subsequently, many people have left and moved to Willowmore, and the number remaining could be less than a 1000. Scholar numbers declined by 66% between 1990 and 1999 (from 389 to 234, Clark pers comm). This trend continues with some of the four primary schools facing imminent closure, and the current rationalisation process resulting in the transfer and retrenchment of teachers (who presently number 15). The depopulation of the Kloof is echoed in statistics for Willowmore magisterial district which show that in 1991 the non-urban population made up 82% of the total population, whereas by 1996 the non-urban population was only 56% of the total population. Possible factors which influence people's decision to move are that: a) people moving to Willowmore may apply for government housing subsidies, b) there is no secondary school in the Kloof, and c) services are bad and expensive in the Kloof. The identified top needs of the community are related to health (ambulance services; first aid workers; clinic facilities), recreation facilities, education (pre-school and secondary school, library facilities, adult literacy), sanitation (82% have no flush toilet) and electricity (74% have none).

According to the 1996 census the population of Willowmore urban area was 6893 with 16.25 % of these being employed, the remainder being unemployed, pensioners or disabled, scholars or under employment age and housewives (Table 2). The largest employer in Willowmore has just closed down resulting in a loss of 100 jobs (Clark pers. comm.). About 29% of non-urban Willowmore was employed, and about 30% of people in the Kloof although 55% of these were casuals employed at harvest-time etc. The StatsSA defined sector employing the largest number of people within the Willowmore urban area is 'community, social and personal services', which employs 30% of those employed (Table 4). These categories are very broadly defined and so it is difficult to say how many enterprises may be tourism-related. However, based on GGP, 'trade and catering', which would include tourism related activities, contributed 18% of Willowmore's (urban and non-urban) GGP in 1994 (up from 17% in 1993), while agriculture contributed 34% (down from 39% in 1993). 'Trade and catering' contributed 27% of employee remuneration, while agriculture only contributed 14% in 1994. In contrast, in non-urban Willowmore, the sector employing the majority of people (71%) is 'agriculture, hunting, forestry and fishing' (this includes nature conservation).

Of those people with an income (employed or pensioners etc.) in urban Willowmore, 59% earn R500 or less a month and 75% are in the same category in non-urban Willowmore. From a household income point of view, 30% of urban households have an income less than R500, 37% of non-urban households, and 19% within the Kloof. Based on Kruger (1997) 45% of those with permanent employment within the Kloof are employed as agricultural workers. Government pension funds and other welfare grants contribute 40.4% of the average household income in the Kloof.

A1.2. Evaluation of Scenarios

Employment and remuneration

Employment in **Scenario 1** would comprise agricultural employment, teachers, police and shopworkers as at present, and those employed in the current BWA. Employment in **Scenario 2** would stem from direct employment in BWA by ECNC and the private sector for rehabilitation, construction and tourism activities, direct employment in Willowmore for construction work, and indirect employment in Willowmore due to increased tourism initiatives generated. Consideration of the latter is beyond the scope of this study and numbers are based directly on Clark pers comm and Clark, 1998).

Under **Scenario 3**, employment would arise from some continued agricultural activities, the BWA and other sources as in Scenario 1, as well as potential new tourist employment. It is unlikely that employment and remuneration within the Kloof would change much without significant capital inputs from the private sector or government. Neither of these are likely to occur unless farms are bought up by investors, which would, from the point of view of the farmers, be the same scenario as if the land were bought and managed by ECNC. However, if the present Baviaanskloof Development Forum and/or Baviaanskloof Private Owners Association were able to access funding through the Regional Development Forum, employment initiatives could perhaps be created.

Employment within **Scenario 4** would come from current agriculture, and there would be increases in BWA both in the short term for building and in the long term for tourist services and maintenance of facilities. It is probable that no utilisation of game for hunting would be possible, although sale of disease-free stock might be possible.

Gross income generated

Economic impacts should include multipliers and be expressed in terms of NPV (allowing one to take into account, for example, decreases in agricultural production due to soil erosion and overgrazing, or changes in income due to changing tourism trends), however, this was beyond the scope of this report.

Economic activities of **Scenario 1** include the present agricultural activities, present BWA activities, retail trade and small scale private tourism initiatives which may be occurring in the Kloof. No information is available on the latter. The Willowmore magisterial district is dominated by livestock farming (mostly sheep and goats), with 98% of agricultural land used as natural pasture (StatsSA 1993), and 87% of gross agricultural income coming from livestock and livestock products. However, because of its unique position and water availability, the Willowmore district earned 99% of the total gross income earned from horticultural products in the three districts of Jansenville, Steytlerville and Willowmore (StatsSA 1993). The gross income for agriculture in Willowmore 1993 was R 14 743 000. The average gross income from agricultural land was R22 / ha, animal and animal products generally earning around R19 / ha and combined field and horticulture products earning on average R 237 / ha (StatsSA 1993). Adjusted to 1999 Rands this would be around R34 / ha – which is probably an overestimate as income from agriculture has most likely not kept up with inflation, and this estimate also ignores sectoral changes over this time period. The percentage of gross income earned from field and horticultural products increased from 10% in 1988 to 13% in 1993, while income from livestock decreased from 90% to 87% over the same period. Agriculture earned 39% of the GGP of R42 930 000 for Willowmore district in 1993 and 34% of R43 860 000 in 1994 (StatsSA 1995). Gross income earned in the Kloof would be 56 000 ha x R34 = R 1 906 000 assuming that the same proportions of grazing, field and horticultural land exist in the Kloof as for the Willowmore district, and adjusting the average gross income for inflation to 1999 Rands. In other words, this would be the gross income foregone if no agriculture took place in the Kloof. BWA visitor numbers and details were obtained for the 1998/1999 financial year. Current rates as well as increased tariffs were used, as present rates are considered to be low and are likely to change.

In order to estimate possible revenues earned by an expanded BWA under **Scenario 2,** various assumptions were made. These were that visitor numbers increased by 50% (not unrealistic considering the low numbers at present), and that occupancy increased from 34% to 55%, also not unrealistic given the present low occupancy, and recent publicity. Occupancy rates in popular game reserves in Southern Africa are between 55% and 60% (Turpie *et al.* 1998). Current tariffs, as well tariffs increased by 60% are illustrated. Information is based on Clark (1998), however, revenues generated from game capture, culling and hunting have been substantially reduced from those of Clark, as present game numbers, likely time to reach carrying capacity, or the expense of large-scale introductions make the projections from Clark unlikely. The figures used are likely to be relatively optimistic for near term (the next five years) earnings. Currently only kudu are perhaps sufficiently abundant to be hunted. Additional income which was not included, may come from general expenditure in shops, restaurants, curio outlets and the preparation and use of hides, trophies and meat of trophy game. These activities would be privatised, and their profits would contribute to the GGP. Effective marketing would be needed to increase the use of the reserve's activities, and to make them financially profitable.

For **Scenario 3**, various assumptions had to be made:

- Stock and land used for grazing would be reduced to 40% of current, and land used for horticultural and field products would be reduced to 60% of current. Gross agricultural income would therefore decrease to about 40% of current.
- Six beds of tourist accommodation would be available per farm at R120 per person per night bed and breakfast.
- Income from hunting would be about 50% of that of the tourist zone of the expanded BWA (Scenario 2). A lower income would be possible due to a lower total area being available for game (game in Scenario 2 being replenishable from other areas, the total BWA providing the carrying capacity, whereas in Scenario 3, only a portion of the "tourist zone" envisaged in the BWA proposal would be available).
- The number of day visitors to the western sector of the BWA is likely to increase compared with current visitor numbers, while the number of overnight visitors and visitors to the eastern sector would be unlikely to change. Day visitors to the western sector were therefore assumed to

increased by 60% (forming 30% of overnight visitors, as compared to 21% currently). The remaining BWA revenue would be approximately the same as for the existing reserve (Scenario 1), although fishing, canoeing and horse-riding might increase.

Gross income from **Scenario 4** would come from current agriculture as in Scenario 1, and the BWA as in Scenario 2 (except that occupancy rates were reduced to 35% given the reduced game viewing opportunities), and excluding game utilisation.

Table 8.1. Summary of employment and gross income estimates for the four scenarios.

	Employ ment		Gross Income
	Numbers	Average pay per person per month	
Scenario 1	340	R 500	R2 144 000 – R2 257 000
Scenario 2	750+	R1 500	R5 945 000 - R8 828 000
Scenario 3	450	R 500	R4 4 59 000 - R4 572 000
Scenario 4	540	R1 000	R4 986 000 – R6 826 000

Other social effects

Reference should be made to Section 8.2.2 which outlines the potential optimistic and pessimistic futures when reading the following. No analysis could be undertaken on the extent of the identified issues.

Besides employment and remuneration increases, and economic multiplier effects, no other benefits to the Kloof community from **Scenarios 1, 3 and 4** were included. Housing and training would not be provided without external funding, and education, medical and other services to the Kloof would be unlikely to improve.

The original BWA proposal suggested that **Scenario 2** would have:
Potential benefits to people relocated from the Kloof:
- Better housing provided in Willowmore
- Better services (medical, schools etc.)
- A lower cost of living (but loss of benefits from living on farms e.g. food, cheap accommodation, land for crops or livestock).

Potential costs borne by people from the Kloof include:
- Disruption of the community
- The above potentially leading to social problems within Willowmore
- A reduction in choice in terms of way of life (presently people can choose to live in the Kloof or Willowmore or own a farm in the Kloof or not)
- A loss of benefits from living on a farm in terms of additional food sources, housing etc. as well as spiritual and cultural aspects.

Potential benefits to government:
- concentration of service beneficiaries (no need to provide services to dispersed BWA community)
- an increased tax base, and a reduced need for unemployment benefits
- increased ability for self-generation of funds and decreased government subsidies

Effects on Conservation Value and Management

Under **Scenario 1**, current land- and water use practices in the Kloof are proving detrimental to the veld due to overgrazing and to the river due to over-abstraction, grading, soil erosion and water-use by alien invasives.

Benefits to conservation from **Scenario 2** would stem from several sources:

- Regional conservation needs through the acquisition of a further veld type.
- Increased biodiversity.
- Improved riverine health.
- Increased self-sufficiency of ECNC.
- Reduced management costs and issues caused by fence-line.

With a firm commitment to improved farming practices, appropriate game stocking rates, negotiating fence-line management problems, under **Scenario 3** there could be:

- Biodiversity increases
- Riverine health improvements

Scenario 4 might improve the financial self-sufficiency of the BWA and ECNC.

Effects on Water

As a result of current land-use practices under **Scenario 1**, the Baviaans River apparently runs dry more frequently than in the past. The river is naturally subject to extreme flood events, which are likely to be exacerbated by increased flood runoff due to denudation of the veld by overstocking, the creation of lands in the floodplains, and the grading of sections of the river. The possibility exists that the environmental requirements of the Baviaans River downstream of the Kloof are not being met, but it is likely to be some time before the instream flow requirements will be established.

Benefits from **Scenario 2** would stem from:

- Improvement in, and sustainability of, riverine health with consequent biodiversity benefits as mentioned in the previous section
- Improved reliability of yield of the Kouga dam due to cessation of irrigation and removal of aliens[12] with consequent potential improvements to:
- Agriculture from irrigation in the Gamtoos Valley
- Supply to Port Elizabeth municipality
- Increased life-span of the dam because of a reduced silt load (as there would be less soil erosion)
- Savings from the postponement of the need to build a new dam due to points 2 and 3.

As mentioned in the section on conservation benefits, without a commitment from the Kloof community regarding water and land-use practices under **Scenario 3**, there are unlikely to be any real benefits in terms of water from this scenario.

There would be no water benefits resulting from **Scenario 4** (as for Scenario 1 and 3).

[12] The Algoa Water Resources Stochastic Analysis (Ninham Shand, 1996) estimated that 3 168 ha of alien infestation in the Langkloof reduced flow by 6.4 Mm^3/a. Similar amounts are likely to pertain the Baviaanskloof.

Chapter 9. Classification and prioritisation of estuaries for determination of the estuarine Reserve

Those not familiar with the terminology of the NWA and implementation should refer to Chapter 4. The classification study, co-ordinated by Dr J. Turpie (UCT), formed part of a broader study, to design a methodology for determining the ecological Reserve for estuaries. The objectives were to:

- devise a methodology for determining the integrity or health status of an estuary, and its conservation importance status, for determination of EMC; and
- determine priority estuaries for carrying out Reserve determination.

The decision-aid process took the form of:

- Running one session of a workshop to define criteria (indices) to be used in the classification
- Advice regarding the formation of the indices and the meaning of weights
- Development of questionnaires to refine indicators and weights

As part of the implementation of the NWA, each estuary will be classified in terms of its present condition and its importance. These conditions are termed Present Ecological Status (PES) and Ecological Importance (EI) respectively. This process led naturally to the formulation of various indices which contribute to measures of PES and EI. At the start of this project there were a multitude of indices which measured various aspects of ecological status, health, integrity, or importance or combinations of these, or for particular groups of fauna or flora. These, or new indices were then to be aggregated *in some way* for an overall classification. The sub-indices and overall index needed to be sufficiently well defined and structured so that they would be robust to use by different practitioners (different practitioners classifying the same resource should reach the same or similar conclusions). At the same time, they needed to be simple and accessible.

9.1 Methods

9.1.1 Development of indices and a value tree

Besides the pre-existing indices, the team tasked with the development of the PES and EI indices had already chosen certain criteria or developed indices which they wished to use. However, some time was taken during a workshop to reassess the criteria to see whether these could be reduced in number or simplified (i.e. trying to conform to the requirements in Section 2.1.1). In general, people were loth to 'let go' issues, even when it was clear that some other measure would to a large extent measure the same impact. The end result was a PES index with 23 contributing (lowest level) sub-indices (Figure 9.1). The same situation arose with the EI index (Figure 9.2) which had 12 contributing sub-indices.

A questionnaire (Appendix 9.1) was sent to the project team, which attempted to guide them through the process of checking the criteria in terms of the requirements given in Section 2.1.1. The questionnaire then went on to assess value function relationships (Section 2.4.1 and Section 3.3) of any quantitative criteria. A questionnaire is far from an ideal format, however, these questions were further addressed in a workshop not attended by AJ.

9.1.2 Weights

The swing weighting concept was discussed and preliminary weights were given by Dr Turpie. The questionnaire included a number of exercises intended to elicit appropriate weights, and these questions were addressed at the meeting mentioned above. The index will be assessed to determine whether the weights are broadly applicable or if different weights need to be used in each application.

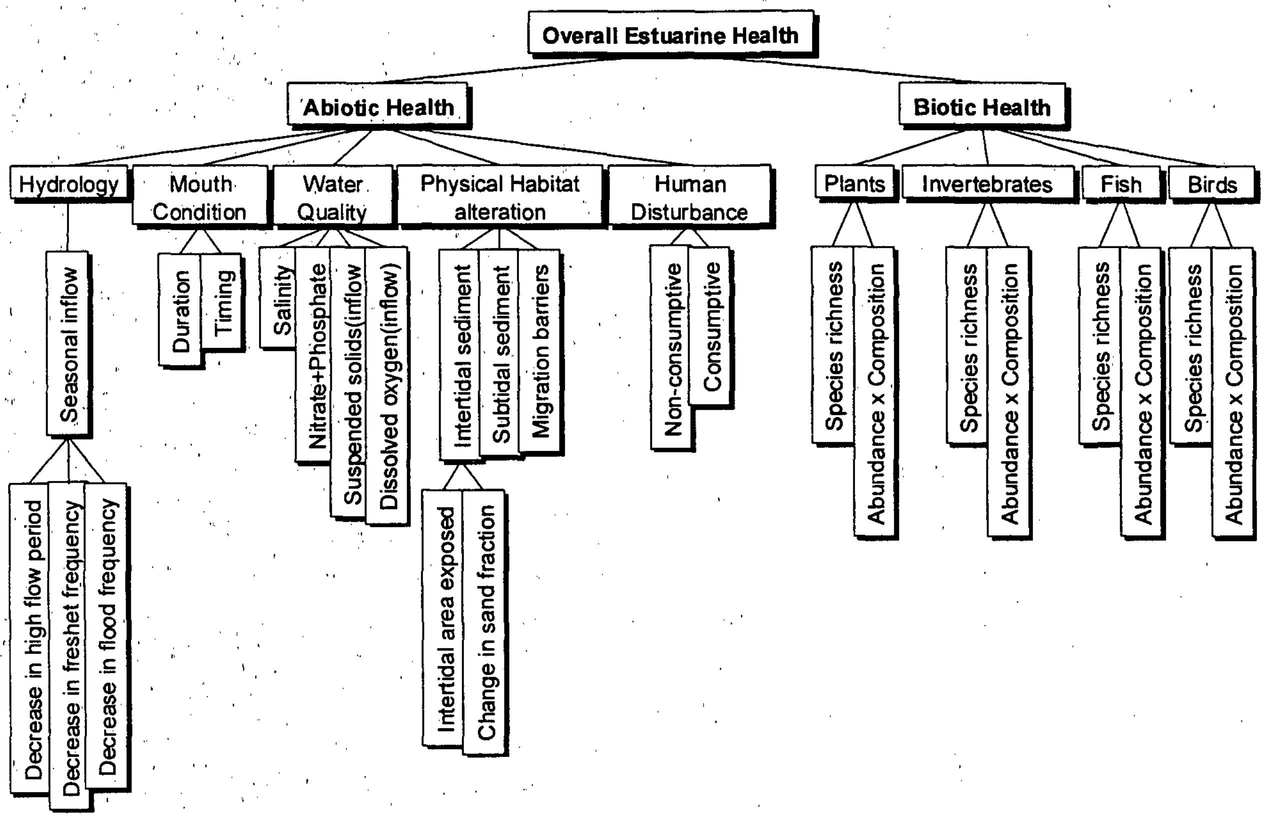


Figure 9.1 Value tree representation of the estuarine health index or present ecological status (PES) index.

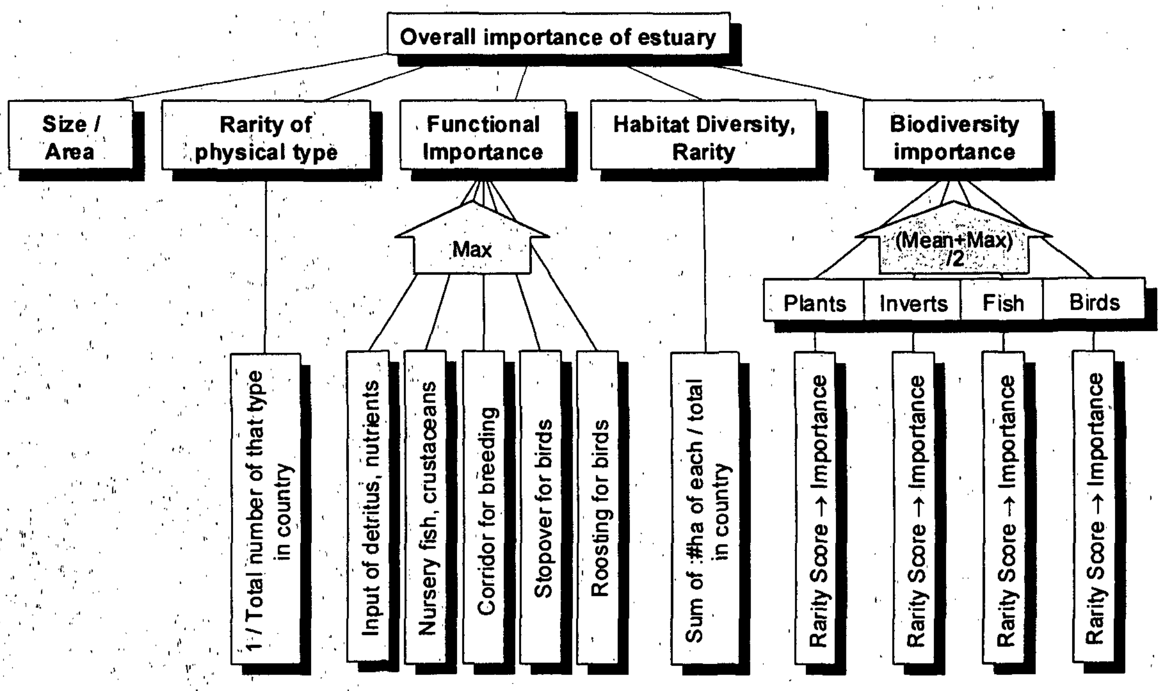


Figure 9.2 Value tree representation of the estuarine importance index.

Appendix 9.1. Questionnaire to assess criteria, value functions and weights for estuaries

The following is a slightly edited version of the questionnaire sent to the project team.
Ideally this stage of the process of developing a scoring system or index would be addressed in a workshop. As this is not possible, I have tried to highlight, in writing, a few points which might guide you in reviewing the index thus far. Specifically, I have included exercises for you to complete for the estimation of appropriate weights for the criteria within the indices.
There are three main areas which need to be critically assessed:

1. The structure of the index and the criteria which form it
2. The scoring systems for the criteria
3. The weights of the criteria

Section 1 and **2** apply to both of the indices, while **Section3a** deals with the weights within the Health Index and **Section 3b** with the weights within the Importance Index. The relevant Tables are included in Section 3, but you will need to refer to them for the other sections as well. Please make any comments about criteria, scoring, and weights on or near the tables and return them to me and cc. your responses to Dr Turpie. Thank you very much.

Section 1: Structure and scoring systems of the Health and Importance indices

Look at the value trees in Figure 9.1 and Figure 9.2 showing the structures for the Estuarine Health Index and the Estuarine Importance Index. Except where specified the scores are aggregated up the tree using a weighted sum. These figures might help you to address the following three issues – imagining estuaries which are unhealthy in bizarre ways might help.

1.1. *Sufficient / complete:* - Are there any issues which have not been included, and which are not addressed by another criterion?

1.2. *Non-redundant & of Minimum size* - Is there unnecessary double counting? Has 'everything' been included without really adding anything in terms of health / importance indices. Is there a multiplication of trivial concerns, confounding interpretation but adding little to the ordering of estuaries. E.g. In the health index, are criteria 5c. and 5d. different to 5a and 5b.

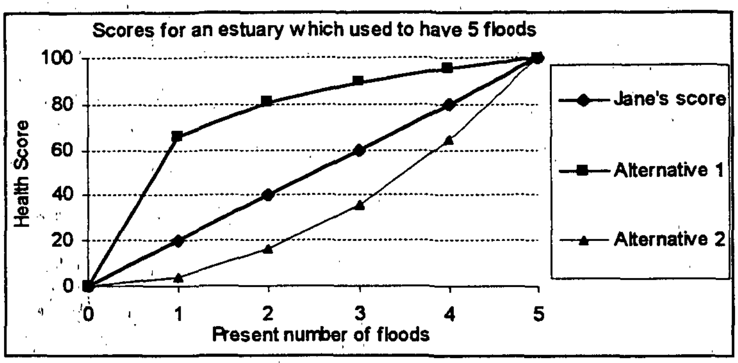
1.3. *Independent* - Can you say how healthy or important a river is with respect to one criterion, without referring to the level of health or importance any other criterion. Would you find yourself saying things like "It depends on..."?.

Section 2. Within each criterion – scoring systems

The score guidelines given within each criterion need to ensure appropriate relationships between the attribute and how it relates to the **health** or **importance** of an estuary - don't assume that there is a linear relationship between an attribute of an estuary and its health or importance.

As an example, (in the health index) lets look at changes in frequency of flooding in an estuary which on average has five floods a year. Presently, the scoring system means that a loss of one flood from the normal level of five is the same, in terms of loss of health, as the loss of one more flood when you have already lost four of them - see the linear relationship (diamonds) in the figure below. Maybe this is so? Or maybe the relative amount of loss in health increases as you lose more and more floods (triangles-power relationship). Or is it the other way around, the biggest loss in health is in losing one flood, after that it doesn't really matter (squares-log relationship)?

Basically, this same question needs to be asked for **all** criteria (in Section 3). I realise it will be hard for you to put yourself through this hoop for each criterion, so perhaps you should concentrate on issues with which you are most familiar. The three most common shapes are as shown in the figure below - there might also be S- or other-shaped relationships. In each case either change the scores within the table, draw the relationship, or describe it. Scoring guidelines for all criteria have been given, some already include non-linear relationships and figures are included for clarification.



Section 3: Relationships between criteria – weights

A weighted sum of scores as used here, implies that an increase in one criterion compensates for a decrease in another criterion. Because we have no common natural scale, the weights need to rescale each criterion scale so that the degree of compensation is acceptable – i.e. the trade-off. For example, if we consider the two criteria:

a. change in duration of opening of mouth
b. change in timing of opening of mouth

Scores for each of these criteria range from 0 to 100. If these two criteria are "equally important" then, all other things being equal, the two estuaries below are equally healthy:

	Duration of mouth opening	Score	Timing of mouth opening	Score
Estuary A	Was 75% of year – now 50% of year	48	Was 3 now 2.45 (of 3 months	82
Estuary B	Was 50% of year - now 75% of year	82	Was 3 now 1.46 (of 3 months	48

If you feel uncomfortable with these being equally healthy it means that the scale of one criterion needs to "shrink" or "stretch" to correct the trade-off. Perhaps you feel that Estuary A is less healthy than Estuary B: therefore the duration of mouth opening is more important than the timing – it then gets a higher weight – say 100. Then think of the of effect timing of mouth opening relative to this – maybe it is 80% as important? It then gets a weight of 80. There are many weights to be considered, again each person should concentrate on weights within their area of expertise. However, everyone should do the final table in each section (comparing all criteria) as this will have the most impact on any final outcome, and everyone should attempt Exercises 1, 2, and 3. Where you can't give a relative importance simply rank the criteria in order of importance – however, relative weights are much more useful.

Section 3a: Weights in the Estuarine Health Index

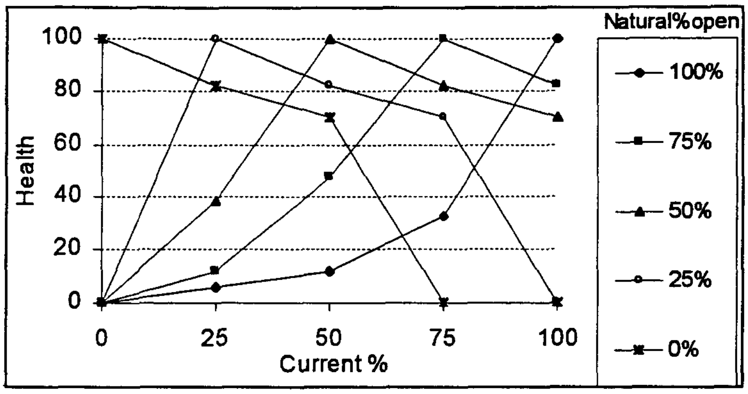
Abiotic variables for inclusion in the estuarine health index

1. Hydrology			e.g.	Weight
1: Seasonal inflow patterns				
1a.	% decrease in period of non-low flows (measure of change in low flow period) *e.g. 10 months to 6 months = (10 – 6) / 10 =*		40%	40
1b.	% decrease in mean annual frequency of freshets *e.g. 20 events to 16 events = (20 – 16) / 20 =*		40%	20
1c.	% decrease in mean annual frequency of floods *e.g. 4 events to 2 events = (4 – 2) / 4 =*		50%	40
		Mean	43%	
	% similarity in Seasonal inflow patterns = 100 – (a + b + c)/3		57%	**80**
2. % MAR remaining				
	% MAR remaining		25%	**20**
% similarity in Hydrology = mean of 1 and 2			41%	

Hydrodynamics and Mouth condition			e.g.	Weight
a.	% change in mean duration of closure, e.g. over a 5 or 10 year period *Scoring guideline: see following table.*		40	50
b.	% change in duration of closure during spring *e.g. Never closed originally, to never closed in present state =*		0	50
		Mean % change	20	
	% similarity in mouth condition = 100 – (a + b)/2		80%	

Scoring guideline for change in mouth condition.

Natural state	Current state 100%	75%	50%	25%	0%
100%	100	33	12	6	0
75%	82	100	48	12	0
50%	70	82	100	39	0
25%	0	70	82	100	0
0%	0	0	70	82	100



	Water quality	Score(e.g.)	Weight
1	% change in axial salinity gradient and vertical salinity stratification *Scoring guideline: Unmodified = 100; largely natural = 80; moderately modified = 60; largely modified = 40; seriously modified = 20; completely modified = 0.*	50	30
2	Nitrate and phosphate concentrations in estuary *Scoring guideline: Unmodified = 100; reduced = score is estimated % of original level; slightly increased = 75; moderately increased = 50; eutrophic = 0.*	80	20
3	Suspended solids in inflowing freshwater *Scoring guideline: Unmodified = 100; slightly increased = 75; moderately increased = 50; heavy load = 25; excessive siltation = 0.*	0	20
4	Dissolved oxygen (mg/l) of inflowing freshwater *Scoring guideline: 0-1mg = 0; 1-2mg = 20; 2-3mg = 40; 3-4mg = 60; 4-5mg = 80; >5mg = 100 points.*	90	10
5	Degree of change in pH in inflowing freshwater *Score guideline: zero change = 100; change in pH of 1 = 80; 2 = 60; 3 = 40; 4 = 20; >5 = 0 points.*	90	10
6	Degree of change in mean annual Temperature in inflowing freshwater *Score guideline: zero change = 100; change by 1°C = 80; 2° = 60; 3° = 40; 4° = 20; >5° = 0 points.*	100	10
	% similarity in water quality = Weighted mean	59%	

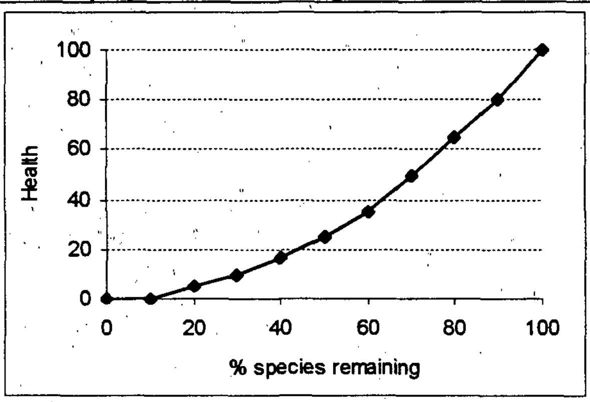
	Physical habitat alteration	% change (e.g.)	Weight
1	Change in intertidal sediment structure and distribution		
1a	• % change in intertidal area exposed *e.g. 50 ha to 60 ha = (60 – 50) / 50 =*	20%	50
1b	• % change in sand fraction relative to total sand and mud *e.g. 50% sandy to 70% sandy = (70 – 50) / 50 =*	40%	50
.	Weighted Mean	30%	**50**
2	Change in subtidal estuary: bed or channel modification, canalisation *Scoring guideline: No alteration = 0%, No resemblance to original state = 100% modification.*	0%	**30**
3	Migration barriers, bridges, weirs, bulkheads, training walls, jetties, marinas *Scoring guideline: score should estimate the extent to which water flow within estuary is impeded e.g. (depending on intensity) No impediments = 0; jetties, training walls = 10; previous plus bridges = 30; previous plus marina = 50; previous plus weirs or causeway = 80. E.g. Swartkops = 20.*	20%	20
	Weighted mean	20%	
	% similarity in physical habitat	80%	

	Human disturbance of habitats and biota	Score(e.g.)	Weight
a	Degree of human non-consumptive activity on estuary, e.g. walking, water-skiing. *Scoring guideline: None = 0, Little = 25, Moderate = 50, High = 75, Very high = 100*	25	10
b	Degree of human consumptive activity (fishing and bait collecting) on estuary *Scoring guideline: None = 0, Little = 25, Moderate = 50, High = 75, Very high = 100*	50	30
c	% of mudflats usually damaged by illegal bait collectors	20	30
d	% of vegetated habitat areas damaged by trampling or boats	5	30
	Weighted mean	40	
	% similarity to state of no human disturbance = 100 – weighted mean disturbance	60%	

Biotic variables in the estuarine health index

This index should be calculated for plants, invertebrates, fish and birds.

Variable	Measurement	e.g.	Weight
1. Species richness	Estimated % of original species remaining		
	Scoring guideline: 100% = 100, 90% = 80; 80% = 65; 70% = 50, 60% = 35; 50% = 25; 40% = 17; 30% = 10; 20% = 5; 10% = 0	90%	25
2a. Abundance	Estimated % of total biomass remaining	130%	
b. Community composition	Estimated % resemblance to original composition.		
	Scoring guideline: No change = 100%	20%	
	Original community totally displaced by opportunistic spp = 0%		
Weighted abundance	= b x c%	26%	75
% similarity to pristine condition = weighted mean of 1 and 2		42%	



Construction of the Estuarine Health Index

Everyone should look at the weights in the table below and try to think about them in the way illustrated earlier: replace the suggested weights with your own.

	Variable	e.g.	Weight
Abiotic (habitat) variables			
1	Hydrology	41	20
2	Hydrodynamics and mouth condition	80	20
3	Water quality	59	20
4	Physical habitat	80	20
5	Human disturbance	60	20
1. **Habitat health score** = weighted mean		*64*	***50***
Biotic variables			
1	Plants	60	25
2	Invertebrates	70	25
3	Fish	60	25
4	Birds	90	25
2. **Biological health score** = weighted mean		*70*	***50***
ESTUARINE HEALTH SCORE = weighted mean of 1 and 2		67	

Could everyone please complete the following:

Exercise 1 and 2: Consider the 6 hypothetical estuaries in each of the tables below. All criteria not specified are equal, the estuaries differ from each other on one criterion only. Which of these estuaries would you consider to be the least healthy? – it must (or should!) be Estuary 1 – it gets a rank of 6. Now consider which is the most healthy. Give this a rank of 1. Now try to rank all of the other estuaries from most to least healthy. In the next column, give the estuary that ranked first a 100 – now try to say how healthy the others are relative to this one (say as a percentage), and put the relative percentage health in this column.

Section 3b: Weights in the Estuarine Importance Index

Please refer to the Value tree for the estuarine importance index shown earlier.

Rarity of estuary type wrt to geographic position.

Zonal Type Rarity Score: $ZTR = 100 \times 1/N_{tz}$, where N_{tz} is the number of estuaries of type *t* within the same biogeographical zone *z* - scores in the range 1 to 100 (Table 13).

Number of estuaries of each physical type in each biogeographic zone, and their ZTR scores.

	Cool Temperate		Warm Temperate		Subtropical	
	Number	Score	Number	Score	Number	Score
Estuarine Bay	0	-	1	*100*	2	*50*
Permanently open	2	*50*	29	*3*	16	*6*
River mouth	1	*100*	7	*14*	4	*25*
Estuarine lake	0	-	4	*25*	4	*25*
Temporarily closed	10	*10*	86	*1*	90	*1*

This index could be extended to include the existence of **unique physical features.**

Habitat diversity

Habitat diversity $HR = 1000 \times \Sigma a_i/A_i$ where a_i is area of the *i*th habitat in the estuary and A_i is the total area of that habitat in the country (1000 = a multiplication factor).

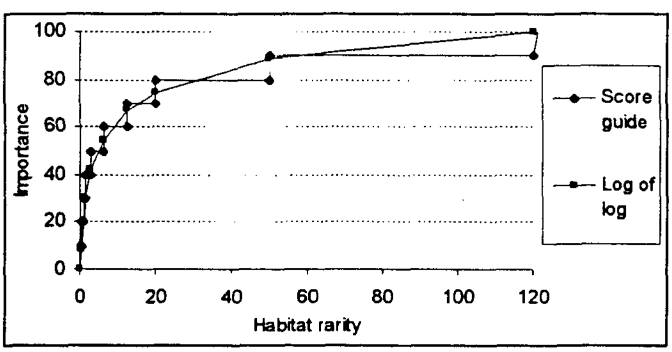
Example data set on estuarine habitats.

Category	Habitat	Area (ha) (or presence data) e.g.	National area (ha)*
Physical	Channel area (MSL)	30	?
	Intertidal Sandflats	5	?
	Intertidal Mudflats	10	?
	Intertidal Rock	0	?
Plant	Supratidal saltmarsh	20	1028
	Intertidal saltmarsh	30	1091
	Mangroves	0	1060
	Submerged macrophytes	35	1562
	Swamp Forest		87
	Reeds and sedges	10	1194
Total estuary area		140 ha	

The habitat rarity index needs translation into an importance score for the index. The distribution of scores is heavily skewed towards the smallest scores: normalising the scores on a scale of 0 – 100 gives very low scores to estuaries that are relatively high in rank. To deal with this, the following scoring guidelines are used → roughly 10% of estuaries are in each score group.

Habitat rarity score	Corresponding habitat importance score	Habitat rarity score	Corresponding Habitat importance score
0.00 – 0.25	10	6.00 – 12.50	60
0.25 – 0.75	20	12.50 – 20	70
0.75 – 1.5	30	20 – 50	80
1.50 – 3.00	40	50 – 120	90
3.00 – 6.00	50	> 120	100

These importance scores can be approximated by taking the log of the log of the habitat rarity score as shown below:



Biodiversity importance

For each of Plants, Inverts, Fish, Birds the biotic rarity score sums the score for each species, based either on abundance or presence/absence:

With abundance data: $r_i = q_i/Q_i$, where q_i = number or area in estuary and Q_i = total number or area in whole country.

With species presence-absence data only: $r_i = 1/N_i$. where N_i = the number of estuaries in which the species occurs in SA.

Thus each species gets a score as a fraction of 1 and Biotic rarity = Sum of r_i

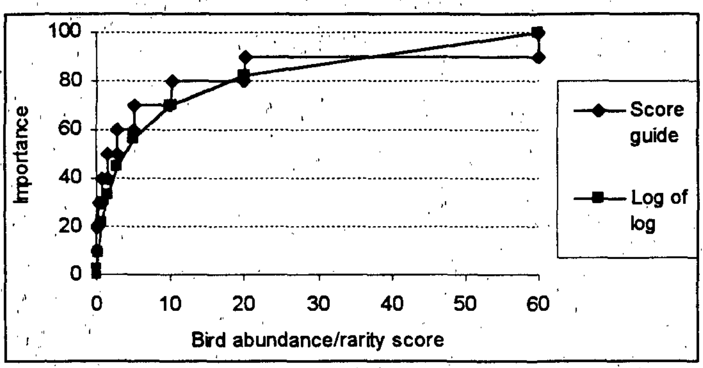
Biotic rarity needs to be translated into importance scores - Scoring guidelines depend on:

- whether abundance data or presence-absence data are being used
- which biotic group is being referred (the score is sensitive to the total number)

Guideline for generating importance scores for birds, based on abundance data.

Bird rarity score	Corresponding bird importance score	Bird rarity score	Corresponding bird importance score
0 – 0.05	10	2.76 – 5.00	60
0.06 – 0.25	20	5.01 – 10	70
0.26 – 0.75	30	10.1 – 20	80
0.76 – 1.50	40	20.1 – 60	90
1.51 – 2.75	50	> 60	100

These scores can be well approximated by taking the log of the log of the Bird rarity score as shown in the figure below.



Preliminary guidelines for plants and fish are given below

Plant rarity score # of spp	→ Plant importance score	Fish rarity score–hypothetical pres-abs	→ Fish importance score
1 – 3	10	0 – 15	10
4	20	16 – 25	20
5	30	26 – 35	30
6	45	35 – 38	40
7	60	39	50
8	70	40 – 44	60
9 – 10	80	45 – 46	75
11 – 14	90	47 – 64	90
> 14	100	> 64	100

Biodiversity Importance Score = **(Mean score (of 4 groups)+ Max score(of 4 groups)) / 2.**

Please consider whether each group should be weighted equally as in the table below:

	e.g.	Weight
Plant importance score	20	25
Invertebrate importance score	60	25
Fish importance score	100	25
Bird importance score	80	25
Mean score	65	**50**
Max score	100	**50**
Biodiversity Importance Score	82.5	

Link with freshwater and marine environment.

Criteria for consideration	Guidelines for Importance score
a. Input of detritus and nutrients to the coastal zone	0 none
b. Nursery function for marine-living fish and crustaceans	20 little
c. Movement corridor for river invertebrates that breed in the marine environment (e.g. river crab *Varuna littoralis*)	40 some
	60 important
d. Stop-over function for migratory birds	80 very important
e. Roosting area for marine or coastal birds	100 extremely important
Overall functional importance score	**Maximum** of scores from a to e

Construction of the Estuary Importance Index

Everyone should consider the weights in the table below, and offer their opinions (place new weights in the appropriate column).

Criterion	Score (e.g.)	Weight
Zonal Type Rarity	50	25
Habitat Diversity	70	25
Biodiversity Importance	88	25
Functional Importance	60	25
ESTUARY IMPORTANCE SCORE = Weighted Mean	70	

Exercise 3: Consider the 6 hypothetical estuaries in the table over the page. All criteria not specified are equal, the estuaries differ from each other on one criterion only. Which of these estuaries would you consider to be the least important – it must (or should!) be Estuary 1 – it gets a rank of 6. Now consider which is the most important. Give this a rank of 1. Now try to rank all of the other estuaries from most to least important. In the next column, give the estuary that ranked first a 100 – now try to say how important the others are relative to this one (say as a percentage), and put the relative percentage importance in this column.
To guide your thinking here, I have included a few estuaries below with their attached importance scores. Relate the scores in the exercise to the estuary with a similar score with respect to that criterion.

ESTUARY	*TYPE-Rarity*	Habitat Score	Plant Score	Fish Score	Invert spp	Bird Score
Knysna	100	100	100	30		100
Berg (Groot)	50			10		100
Kosi	25			100		100
Mhlathuze	6	100	70	100		
Tugela	25			100		90
Swartkops	3	100	100	30		100
Nhlabane	25	50	80	100		70
Breë	3	90		20		90
Mbashe	6	90	90	50		60
Mdlotane	1	100	70	100		50
Mzimvubu	6	100	30	60		
Mkomazi	6	60	60	90		60
Great Kei	3	80	90	40		30
Tongati	1	80	45	100		60
Palmiet	3	60	10	10	3	80
Ntlonyane	1	50	70	40		
Manzimtoti	1			90		70
Umgazi	1	30	60	60		
Storms	14			20		10
Goda	1	40	10	40		30
Mtentwana	1	20	20	75		
Mzimkulu	6			90		40
Mzimayi	1			90		10
Elands	14			20		

Estuarine Health Index (Refer to the explanation on the previous pages)

	Hydrology Low-flow duration	**Mouth condition** *Duration of closure*	**Salinity** *Axial and vertical salinity gradient*	**Physical Habitat** Intertidal area exposed	**Human Disturbance** Degree of fishing and baiting	**Rank** (healthiest = 1, least healthy = 6)	**Relative % healthiness**
Estuary1	Increased from 6 to 9 months = 50	from 75% to 50% = 48	Moderately to largely modified = 50	Increased from 50 ha to 75 ha = 50	Moderate = 50	6	
Estuary2	Increased from 6 to 9 months = 50	from 75% to 50% = 48	Moderately to largely modified = 50	Increased from 50 ha to 75 ha = 50	None = 100		
Estuary3	Increased from 6 to 9 months = 50	from 75% to 50% = 48	Moderately to largely modified = 50	No change = 100	Moderate = 50		
Estuary4	Increased from 6 to 9 months = 50	from 75% to 50% = 48	Unmodified = 100	Increased from 50 ha to 75 ha = 50	Moderate = 50		
Estuary5	Increased from 6 to 9 months = 50	No change = 100	Moderately to largely modified = 50	Increased from 50 ha to 75 ha = 50	Moderate = 50		
Estuary6	No change = 100	from 75% to 50% = 48	Moderately to largely modified = 50	Increased from 50 ha to 75 ha = 50	Moderate = 50		

	Mouth condition Duration of closure	**Plants** Abundance x Composition	**Inverts** Abundance x Composition	**Fish** Abundance x Composition	**Birds** Abundance x Composition	**Rank** (healthiest = 1, least healthy = 6)	**Relative % healthiness**
Estuary1	from 75% to 50% = 48	60% remain x .75 similar = 50	60% remain x .75 similar = 50	60% remain x .75 similar = 50	60% remain x .75 similar = 50	6	
Estuary2	from 75% to 50% = 48	60% remain x .75 similar = 50	60% remain x .75 similar = 50	60% remain x .75 similar = 50	No change = 100		
Estuary3	from 75% to 50% = 48	60% remain x .75 similar = 50	60% remain x .75 similar = 50	No change = 100	60% remain x .75 similar = 50		
Estuary4	from 75% to 50% = 48	60% remain x .75 similar = 50	No change = 100	60% remain x .75 similar = 50	60% remain x .75 similar = 50		
Estuary5	from 75% to 50% = 48	No change = 100	60% remain x .75 similar = 50	60% remain x .75 similar = 50	60% remain x .75 similar = 50		
Estuary6	No change = 100	60% remain x .75 similar = 50	60% remain x .75 similar = 50	60% remain x .75 similar = 50	60% remain x .75 similar = 50		

Estuarine Importance Index (Refer to the explanation on the previous pages)

	Rarity of physical type Zonal type rarity	**Habitat diversity**	**Biodiversity** Birds	**Biodiversity** Plants	**Functional importance**	**Rank** (most important = 1, least important = 6)	**Relative % importance**
Estuary1	Warm temperate, river mouth = 14	Score 50/100	Score 50/100	Score 50/100	Score = 60 (Important function)	6	
Estuary2	Warm temperate, river mouth = 14	Score 50/100	Score 50/100	Score 50/100	Score = 100 (extremely important function)		
Estuary3	Warm temperate, river mouth = 14	Score 50/100	Score 50/100	Score = 100	Score = 60 (Important function)		
Estuary4	Warm temperate, river mouth = 14	Score 50/100	Score = 100	Score 50/100	Score = 60 (Important function)		
Estuary5	Warm temperate, river mouth = 14	Score = 100	Score 50/100	Score 50/100	Score = 60 (Important function)		
Estuary6	Warm temperate, estuarine bay= 100	Score 50/100	Score 50/100	Score 50/100	Score = 60 (Important function)		

Chapter 10. Web-based structures for implementing MCDA

10.1 Internet-based Group Decision Support Systems

An interactive people-oriented computer system is needed to effectively support decision making in solving semi-structured or unstructured decision problems. This kind of computer system is called a Decision Support System (DSS), a term coined in the 1970s (Gorry and Scott Morton 1971, Gerrity 1971, Keen and Scott Morton 1978) based on the concepts of electronic data processing and management information systems.

DSS are computer-based systems that can support some or all phases of decision making. They may include various subcategories according to different points of view. For example, from the academic research standpoint, DSS may include (a) Group Decision Support Systems that support decision making through telecommunication and networks to groups consisting of individuals in different places and at different times, (b) Intelligent Decision Support Systems resulting from the interdisciplinary combination of artificial intelligence particularly expert systems and knowledge engineering and the traditional DSS methods, and (c) Distributed Decision Support Systems that encompass many physically separated but logically related information processing nodes each of which contains some facilities capable of decision support, etc. From the application point of view, DSS may include specific DSS, DSS generators and DSS tools. Group decision support requires integration of decision-theoretic approaches with communication facilities, and different visualisation modes, and should be tailored to the different educational backgrounds of their users.

Nowadays internet web browsers are popular among ordinary people, and browsing the internet might be an instinctive skill to many people in the near future. With the development of networking technology and Internet communication, decision-makers can be connected remotely to the network server using a Web browser or some other communication tools. Internet based DSS enables users to have access to documents and other information in distributed databases, knowledge bases and other information systems via appropriate intelligent tools. Interactive information appears in the form of Hypertext Makeup Language (HTML) pages, which guide the entire procedure of system operations. Users need only follow the flow of the HTML pages in order to fully make use of the system.

10.2 The objectives of the WRC decision support system[13]

The objective of the WRC DSS is to support the processes of decision making by providing structure, tools, procedures, and data for the decision-making processes. The process of decision making has been described as consisting of several distinct and iterative stages (see Chapter 3): problem structuring, evaluation, aggregation and implementation. The WRC DSS supports all of these stages except implementation, which mainly concerns the planning of tasks to carry out the decision made. The problem structuring stage results in the generation of alternatives, criteria identification and value tree construction. The evaluation phase elicits subjective judgements and value functions for evaluating alternatives (i.e. the alternatives are assessed according to the criteria in the value tree). The aggregation phase elicits weights for measuring trade-offs between criteria and calculates the weighted utility of each alternative. Finally, the sensitivity of the utility to weights and scores can be examined.

[13] An version of the WRC DSS is at http://tjstew.sta.uct.ac.za/index.jsp, but users must be registered to access the functional parts. It is intended that the final version will be housed at the Computing Centre for Water Research.

Water resource management decision-making will involve various participants including multiple stakeholders[14], domain experts, and other necessary mediators. The WRC DSS supports group decision making, which allows a group of stakeholders working together as a team to share information interactively, generate ideas and actions, choose alternatives and negotiate solutions.

The aim of the WRC DSS is to take advantage of the latest computer, MCDA (including SBPP), and Internet communication technology to help achieve the most equitable overall benefit with the least cost to individuals, user-sectors, geographic regions and international partners. The WRC DSS runs under a web browser through the Internet. There is no specific requirement for operating platforms. It needs Netscape Communicator 4+ or Internet Explorer (IE) 4+. The WRC DSS runs optimally under Internet Explorer. The following sections describe the WRC DSS in terms of system functions and architecture.

10.3 System Functions

The WRC DSS offers internet-based group decision-making support. Group decision making for a particular case study (e.g. catchment planning in Chapter 7) can be carried out by several stakeholders, each representing different interests, and an analyst who acts as a facilitator. This occurs without geographical restriction as users only need internet access for a particular case study. The system may be used in different ways by different people: the system administrator, the analyst (who may be the same as the administrator) and the stakeholders. The WRC DSS (Figure 10.1) is described below according to the functions relevant to stakeholder groups, the analyst, and the system administrator.

10.3.1 Administrator

The administrator is responsible for registering the stakeholders and the analyst, which provides them with passwords, and specifies which tasks they have rights to perform.

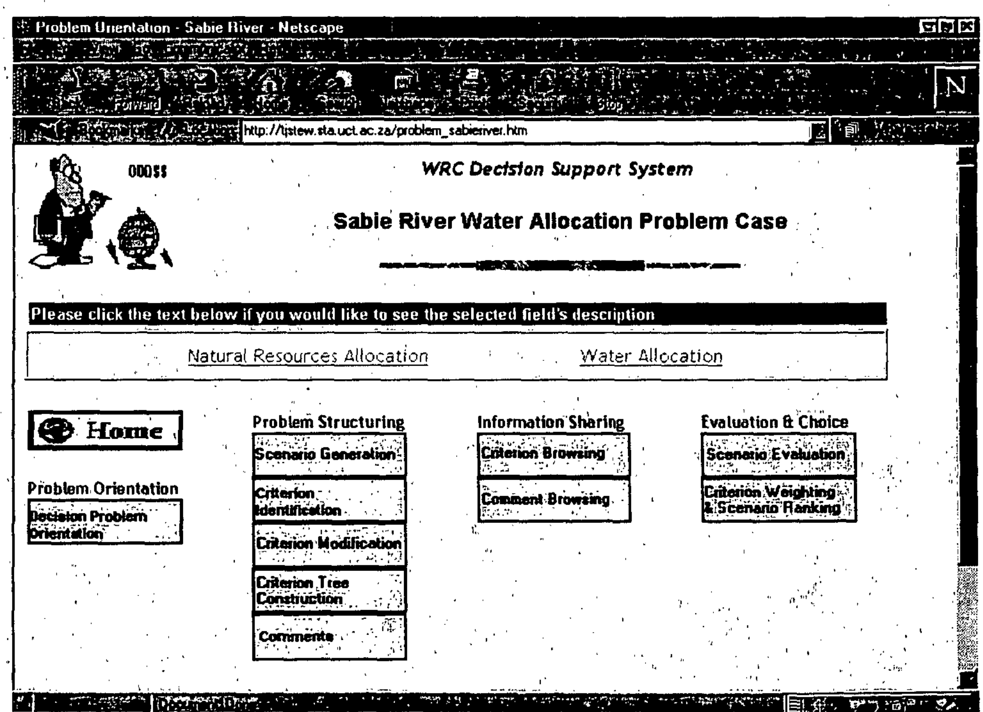


Figure 10.1. Main user interface after log-on.

[14] The term stakeholder is used here to include interest groups as well as those responsible for making decisions.

10.3.2 Stakeholder group functions

The functions for each interest are basically the same as those of the analyst, except that there are some constraints on what functions they can perform. For example, the foreground scenario set cannot be copied to other users. Criteria, comments, scenarios, evaluation data, weights, and other relevant information can be stored and retrieved later on by the users.

Problem structuring (see Section 3.2)

- Identify and edit criteria: Criteria are identified for the specific user interest. They can be modified at a later stage. Users can also browse the criteria input by other users.
- Communicate with each other via the "noticeboard": Each user can make a short comment on various subjects such as criteria and alternatives during different stages of decision making, and can browse the comments input by other users.
- Examine data (background & foreground sets): Each user can view the full background set of scenarios for the study under consideration and the foreground scenario sets of himself and others[15].
- Create personal foreground set: Extra scenarios can be added to the foreground set by each user (possibly by adding from the background set), but the existing scenarios in the fore- and background sets cannot be modified by the users (only the analyst can alter these).
- Construct value tree: The value tree can be constructed for each user interest. Criteria group (or tree node) names can be selected from existing criteria, and new criteria can be added by simply adding a new name (Figure 10.2). The upgraded criterion data is saved automatically when the tree is saved. Users can also browse the value trees of other users.

Evaluation (see Section 3.3)

- Scoring of scenarios: The scoring of scenarios is done either directly on a thermometer scale or via graphs of value functions. Scenarios can be evaluated according to each criterion on a thermometer scale from 0 (the worst) to 100 (the best). Scenarios can also be evaluated according to a value function relating a scenario attribute to the relevant criterion's value (Figure 10.3). These evaluation results are also reflected on a thermometer scale from 0 (the worst) to 100 (the best). The evaluations and value functions of other users can also be viewed.
- Aggregation: Criteria under a parent criterion are weighted using the thermometer scale format, which is reflected in bar graph format (Figure 10.4). The weights are renormalised to sum to one at each level of the value tree. The weight data input by other users can be viewed.
- Value paths: The value paths (showing scores for each criterion) for each interest can be shown after scenario evaluation and criterion weighting.
- Overall ranking of scenarios: The overall ranks of the scenarios for each interest (not for the case study as a whole) can be shown after the scenario evaluation and criterion weighting.

Sensitivity analysis

The system supports basic sensitivity analysis by the stakeholders who can check changes in the rankings and ratings of scenarios after changing the weights of the criteria. The scenario order is shown dynamically on a thermometer scale.

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[15] A background scenario set is a pool of scenarios that is sufficiently rich so that all parties can find a satisfactory alternative. Through judicious interpolation (e.g. using principles of experimental design - improved methods are the subject of on-going research), virtually any scenario can be found within it. A foreground scenario set is needed for the participants to compare a few alternatives directly. Refer to Stewart et al. (1993) and 0 for further explanations of the concepts of fore- and background scenario sets.

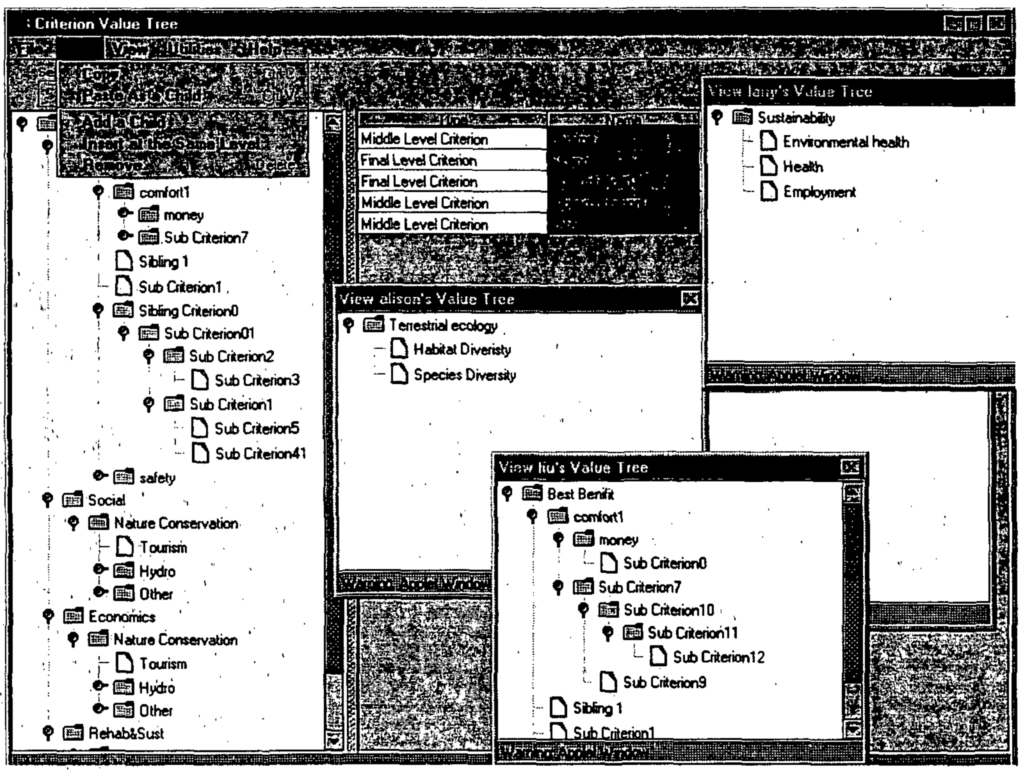

Figure 10.2. Value tree construction interface.

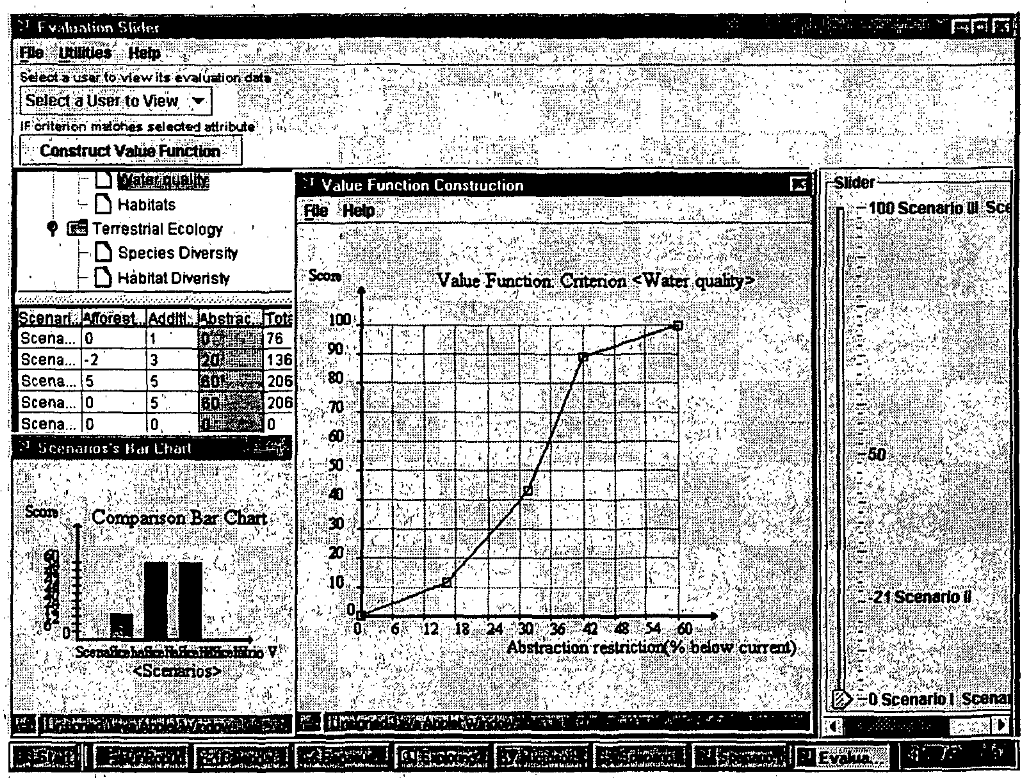

Figure 10.3. Scoring using the value-function method.

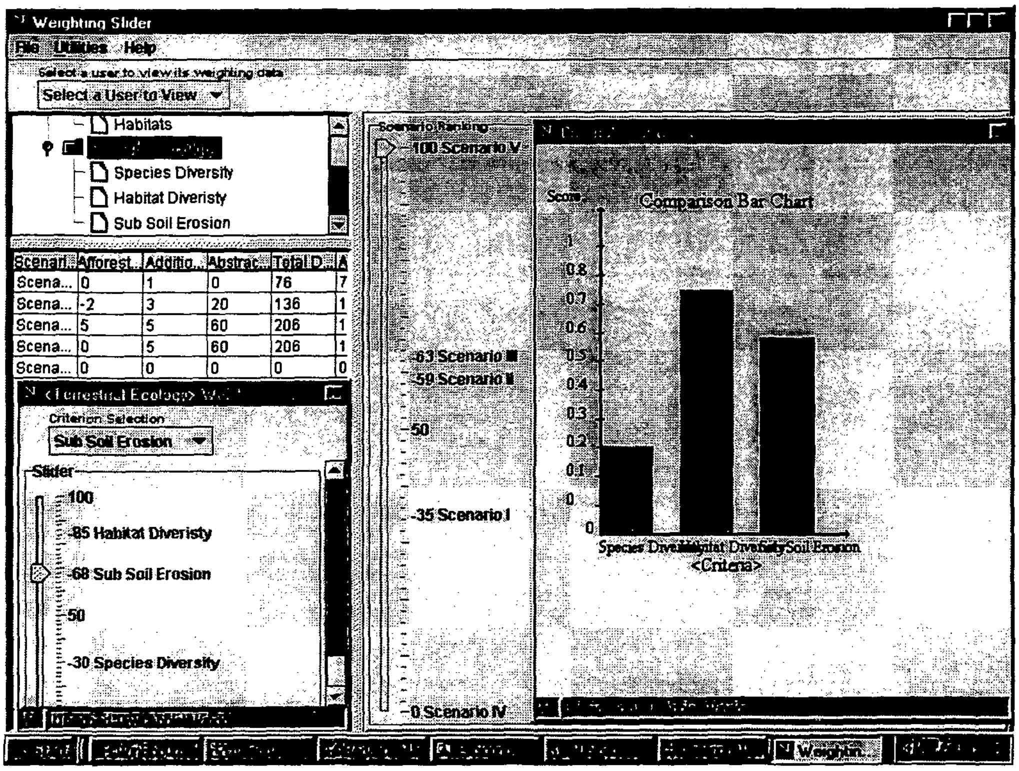

Figure 10.4. Criteria weighting interface.

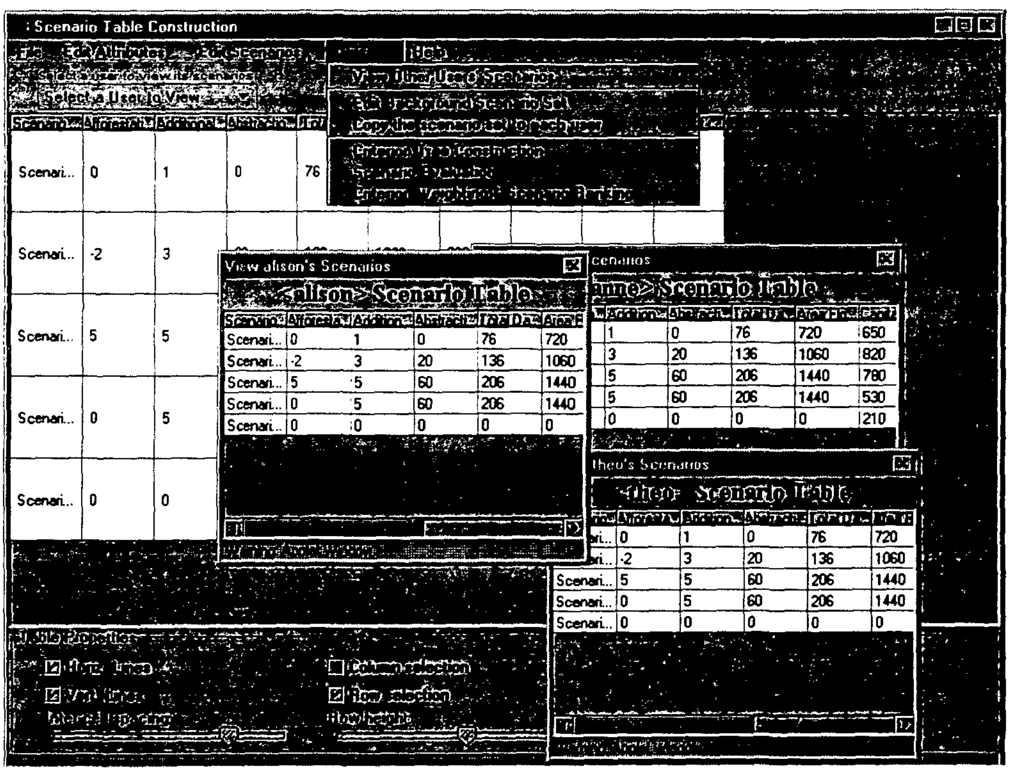

Figure 10.5. Scenario construction interface.

10.3.3 Analyst

The analyst does the basic structuring of the case study and can browse any comments and data input by other users. By accessing these, and through any other communication necessary the analyst will:

- Specify (edit) foreground set and background set: The background set is provided by the analyst after consultation with the stakeholders and the first inputs from them in the problem structuring stage. Other users can then view these. The analyst can edit and update the foreground scenario set and distribute a copy to each user (Figure 10.5). The analyst can browse the extra scenarios input by other users.
- Perform the overall aggregation: The analysts can identify the overall value tree, through linking the criteria, criteria groups or value trees of the stakeholder groups to analyst-specified criteria. In other words, a stakeholder group's value tree is imported into the overall value tree, through associating it to a specific criterion in the overall value tree. Similarly, the analyst will input overall weights based on the users' inputs. A final overall rank of scenarios for the problem case can be obtained and basic sensitivity analysis can also be done.
- Perform the overall sensitivity analyses.

10.4 System composition and architecture

10.4.1 System Composition

The WRC DSSS has three main components, the system orientation component, the system administration component, and the main part, described above, where scenarios and criteria are specified, and scenarios are evaluated. System orientation is designed to familiarise users with the system and help them with operation of the system. System administration is responsible for the administration of users such as registering stakeholders, analysts, and case studies. The system administration shows which user has accessed the system and when.

The main part consists of the following modules which may be accessed iteratively:

- Identifying and editing criteria;
- Inputting comments;
- Constructing criterion value trees;
- Viewing scenarios (the facilitator can build the scenario set while stakeholders may add scenarios);
- Compare scenarios according to the criteria; and
- Weight criteria and aggregate scores

10.4.2 System implementation techniques and architecture

Java is extensively used in the implementation of the WRC DSS. The Java programming language is operation platform independent i.e. the Java programs can run on almost any platform without modifying the codes. Java is used in a variety of ways, perhaps the most publicised is the Java applet. Applets, which are used only on the client side of systems, are Java application components which are downloaded, on demand, to the part of the system which needs them. Therefore, the client-machine interface with the user may range in complexity from simple HTML forms to sophisticated Java applets. However, Java can also be used to create desktop applications and web servers and to extend web servers with customized processing. The latest Java technology provides servlets techniques among other enhancements. Whereas, applets are Java programs running on the client's web browsers, servlets are the applet counterparts running on the web server side. Applets and servlets may implement the same functionality, the difference between them being that servlets do not have a user interface while applets do. Since servlets run inside servers, they do not need a graphical user interface.

The WRC DSS is implemented using the so-called client/server architecture. Java servlets run on the server side for data collection, data analysis and information distribution. Applets and other applications run on the client side to interact with the stakeholders. Databases are stored on the server and can be accessible to the servlets. Object oriented Java programming and internet browsers offer a wonderful opportunity for group DSSs to be implemented in a client/server mode. The WRC DSS uses them to implement the client/server architecture, which has three tiers (Figure 10.6).

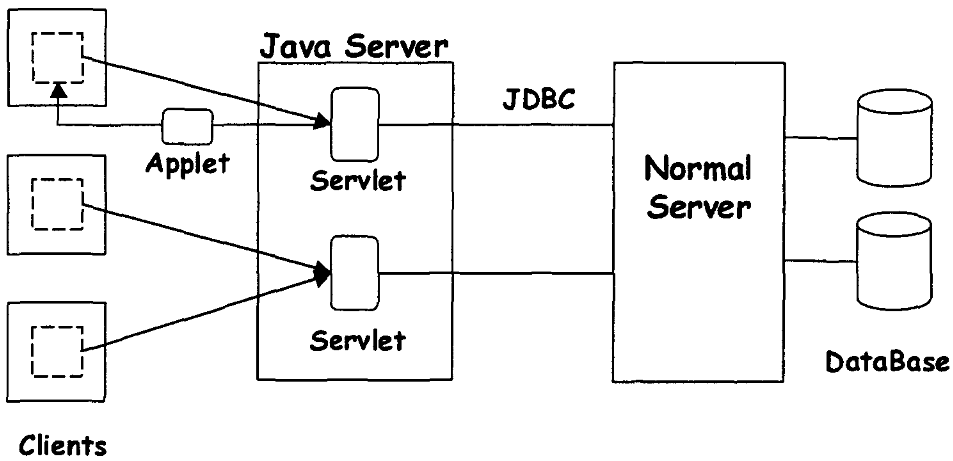

Figure 10.6. The three tier architecture of the WRC DSS. JDBC= Java Database Connectivity.

The first tier will use any number of Java enabled browsers, which are built on personal computers or workstations. Complex user interface tasks can be handled by Java applets downloaded from the second tier servers; simpler tasks could be handled using standard HTML forms. The second tier of such a system will consist of servlets which encapsulate the logic of the application. Servlets may be used to connect the second tier of an application to the first tier. The third tier of the system consists of data repositories.

10.5 Future Improvements

Further testing and debugging is needed as performance under the widely different conditions likely in real world applications could not been tested. The access speed will be dramatically improved after the system is moved to a more powerful server. Addition of other functions such as system configuration for different users, the ability to keep different versions of the same analysis (e.g. with different weights or tree structures), email services, importation and exportation of Excel data, upgrading of user interfaces, links to ArcView, etc., are ongoing.

Chapter 11. Technology Transfer Actions

11.1 A substantial portion of the research reported here can be classified as "action research", in the sense of working with other groups of researchers, managers or planners in addressing water and related land-use management problems. As part of this process, these other groups have become informed about the methodologies of SBPP and MCDA.

11.2 The project team has developed a familiarization course aimed at those concerned with research and management issues in water resources planning (see also conclusions and recommendations in the next chapter). The first presentation of this course will be offered by the project team at no further charge (i.e. being viewed as part of the technology transfer actions of the project).

11.3 Once the internet-based decision support system has been fully tested in follow studies, we shall liase with CCWR about making the software available on an ongoing basis.

11.4 The project team has participated in teaching on the MSc programme in conservation biology at UCT, presenting principles of MCDA in conservation management. This has also led to participation in and support of several projects, including projects which explored the use of environmental economics evaluation tools.

11.5 Research work from this project has led to 3 chapters in books, 2 journal papers, and 12 conference presentations (4 local, 1 each in Namibia and Zimbabwe, and 6 internationally, 3 of which were invited papers). Three further papers are in preparation or have been submitted for publication, and it is expected that two of the co-authors of this report will complete their PhD degrees on work related to the project within the next year.

Chapter 12. Conclusions and Recommendations

12.1 The Scenario Based Policy Planning (SBPP) and Multi-criteria Decision Analysis (MCDA) procedures developed in the previous and current research reports provide practical means whereby the interests of a variety of different stakeholders, including both quantitative and qualitative criteria, can be taken into account in a structured and defensible manner.

12.2 The development of the SBPP/MCDA procedures foreshadowed many of the requirements of the National Water Act of 1998 (and of other environmental legislation) to take such interests and criteria explicitly into account when developing water management strategies. The SBPP/MCDA approach provides in fact an operational framework within which the intentions of the act can be realized. The approach is well-grounded theoretically, and has been demonstrated empirically in a number of case studies.

12.3 In order to realize the full potential benefits of SBPP/MCDA for water resources management in South Africa, it is essential that the methodology be made widely known amongst role players concerned with water management issues. These would include officials of the Department of Water Affairs and Forestry, members of Catchment Management Agencies, and researchers. The current project team has developed a familiarization which should be presented at regular intervals.

12.4 Further research is necessary to address the following issues:

12.4.1 Effective means of integrating the SBPP/MCDA procedures into the regular operational activities of catchment management agencies and other groups concerned with assessing and recommending flow requirements and management plans.

12.4.2 Full development and implementation testing of internet-based software support systems, as described in Chapter 10.

12.4.3 The effective integration of spreadsheet, GIS and other data management systems into the MCDA software.

These issues are receiving attention in a follow-up project being funded by the Water Research Commission.

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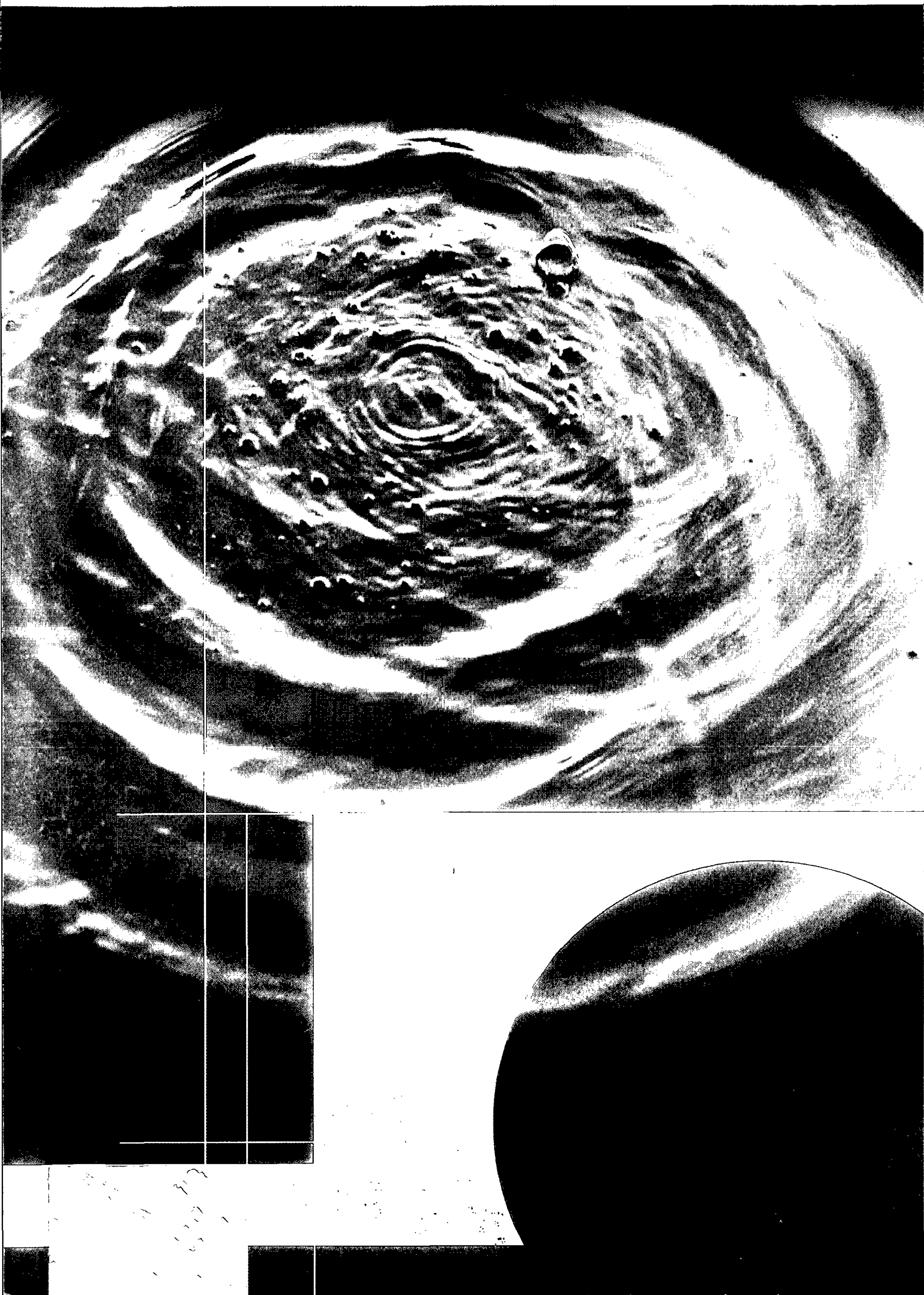

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