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MCDA Framework for Fishing Rights Allocation in South Africa

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Abstract

The work discussed in this paper relates to the allocation of fishing rights within the Western Cape province of South Africa. Many of these fisheries are under threat through over-exploitation, and yet are a traditional source of livelihood in many communities. We describe a sequence of interventions during which principles and processes of multiple criteria decision analysis (MCDA) formed the framework for structuring the problems, for facilitating group consensus on the decision making process, and for designing a decision support template for use in future allocations. Interactions with community representatives and with the the national Department of Environmental Affairs and Tourism revealed a high degree of consistency in perceptions of the management goals that need to be taken into consideration. These goals could be structured and summarized in the form of an integrated value tree, which in turn formed the basis for a formalized decision support structure that could provide a transparent, coherent and auditable basis for the allocation of fishing rights in a fully goal-directed manner.

keywords: Multiple Criteria Decision Analysis; Fisheries Management; Decision Support

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1 Introduction

In many developing countries, the government serves as the main apparatus for attaining the goals of growth and development. Apart from these conventional goals, the South African government faces the additional task of transforming the economy and society from the apartheid past, i.e. to achieve a pattern of economic participation that better reflects the demographics of South Africa and to better distribute resources amongst the people of South Africa.

The fishing sector is one of many in the process of being transformed in South Africa, but has its own unique set of challenges. The goals of transformation need to be balanced against protection of resources, many of which are in a dire state, so that access needs be limited.

Our project concentrated on the Western Cape fisheries, which accounts for about 90% of the total South African fisheries value (Wesgro, 2001), and fishing communities, the geographical position of which is illustrated in Figure 1. Commercial fishing peaked in the 1960s and 1970s, and stocks have dwindled in many fisheries since then leading to increased management actions in the form of minimum size limits, closed seasons, gear restrictions, company and individual quotas. Until the very recent past (early, mid or late 1990s depending on the fishery), allocations tended to be made to a relatively small number of larger fishing companies in the commercial industry which tended also to be white dominated (although not exclusively so). In parallel with the commercial sector, small-scale (permit-based) and "informal" (no permit) sectors continued to operate, mainly in the less capital intensive, more accessible fisheries (e.g. line fishery, west coast rock lobster, abalone, beach seine and gillnets).

New fisheries legislation was adopted in 1998 (Republic of South Africa, 1998), and after some years of uncertainty, a new allocation system emerged by about 2001. With the coming of democracy and with the new legislation, there were high levels of expectation within traditional fishing communities of gaining access to fishing rights, but many were disappointed and rightly or wrongly accused government and others of mismanagement and corruption. Levels of poaching of species such as abalone sky-rocketed (because of high demand and prices), poverty in fishing communities seemed to worsen and the communities became split into camps of rights-holder/non-rights-holder or poacher/non-poacher.

We have thus a juxtaposition of overexploitation of marine resources, poverty, and a lack of skills and community cohesion. In this context, it is imperative to accompany new policies with adequate support to communi-

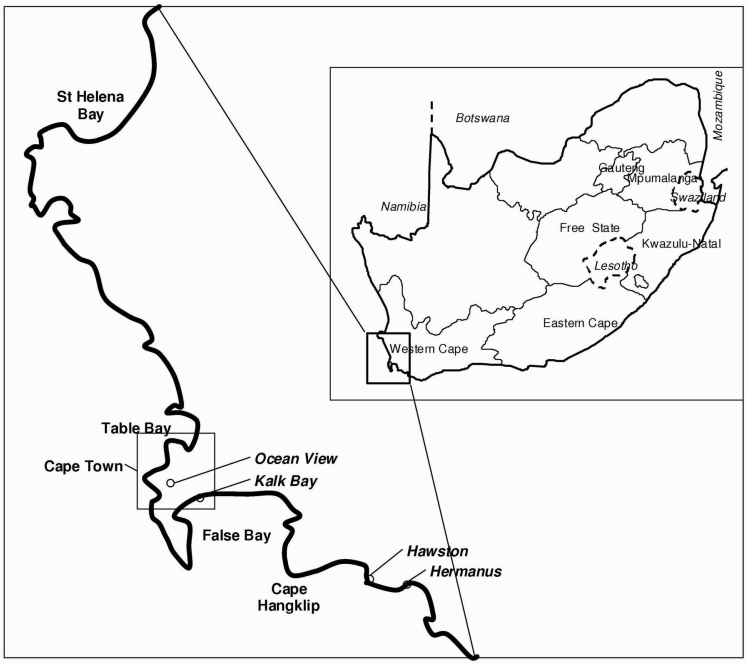

Figure 1: Western Cape Fishing Areas

ties and previously disadvantaged individuals so that they can acquire the skills needed to participate in the economy and deal with or respond to changes in management approach, including the allocation process. A just and broadly acceptable process for allocating fishing rights, and the empowerment of local peoples to make effective and efficient use of these rights, is thus critical both to the protection of the fish stocks and related ecosystems and to the long run alleviation of poverty in these areas.

Against this background, the project which is reported upon here was launched as part of a Dutch-funded international programme on poverty reduction and environmental management (PREM), details of which may be found at www.prem-online.org. In describing the research methods to be adopted, the contract proposal (accepted in 2004) stated: *The overall research methodology can be described as "action research". In other words, the intention is for the research team to involve themselves deeply in real world problems, applying the various decision support and management science tools at their disposal. The experiences will be recorded, analysed and reflected upon in order to extract lessons for future interventions.*

The purpose of the present paper is thus to describe this action research process, and to "analyse" and "reflect on" the experiences gained. More specifically, our approach was to use principles from multiple criteria decision analysis (MCDA), cf. Belton and Stewart (2002) as the framework for structuring views of the underlying problems with different stakeholders, and to extend these into proposals for a decision support template (applicable to a range of fisheries). The use of MCDA as a group problem structuring tool has been discussed by other authors. These discussions include controlled experiments (Davey and Olson, 1998), electronic support systems (e.g. Hämäläinen, 2004), and a number of applications studies especially in environmental impact assessments (e.g. Bell et al., 2001; Bojórquez et al., 2005; Kangas et al., 2001). By adopting the action research approach, in this paper we seek to apply the concepts in a setting of extremely diverse stakeholder groups, and to reflect on the practical value and validity of the approach.

We describe first the separate interactions with community representatives and with the Chief Directorate of Marine and Coastal Management (MCM) of the national Department of Environmental Affairs and Tourism (DEAT). A high degree of consistency of management goals between these groups emerged, and summarized in the form of an integrated *value tree*. This value tree formed, in turn, the basis for a more formalized decision support structure in order to provide a transparent, coherent and auditable basis for the allocation of fishing rights in a manner which addresses all identified community and national objectives.

2 Problem Structuring – Community Level

Two study frames were selected for the purpose of this project, namely a rural fishing community (which we shall designate as the Hawston/Hermanus community) located along a stretch of coast about 100-150km east of Cape Town, and a more urbanized community within the boundaries of the City of Cape Town. (See Figure 1 for the locations of these communities). For practical purposes, it was convenient to split the urban community into two sub-groups denoted as Kalk Bay (largely made up of small boat owners operating out of a fishing harbour of that name) and Ocean View (residents of a village created under earlier apartheid legislation). In the case of the Hawston/Hermanus group, a public invitation was initially issued in the press for local fishing communities to attend an information meeting. This meeting elected a smaller group of representatives to participate in the workshop

which was ultimately attended by 14 representatives. Delegates to the Kalk Bay workshop were small boat owners identified by the Harbour Master, although only 4 of this sub-group attended. The Ocean View village is largely a fishing community, many of whom are represented by the Artisinal Fishers Association, and it was this Association which nominated the 17 delegates to the workshop.

Each workshop lasted about 3–5 hours, and started with opportunities for free expression of concerns by the participants, after which a more formalized brainstorming session using "post-its" (as described in Belton and Stewart, 2002, pages 41–42). The approach is essentially similar to the oval mapping approach, described, for example by Eden and Ackermann (1998, Chapter P2), but made use of more readily-available materials. Eden and Ackermann (1998) do caution that the use of standard post-its can lead to "rectangular thinking" by being aligned in rows and columns, but we deliberately clustered post-its partially overlapping each other in random orientations. These post-it sessions were used to capture perceptions of the problems, goals and potential courses of action, and were subsequently summarized in the form of causal maps, which were used during subsequent discussions to confirm that views of these communities had properly been captured and represented.

Two sets of questions were posed for purposes of the "post-it" sessions, namely (1) *What does having or not having a fishing right mean to you personally or your community* and (2) *What should MCM's [*Marine and Coastal Management*] aims and goals be; and what process should be followed.* Participants were invited to post these on sheets along the walls, trying to group similar concepts together. Once the rate of new ideas being posted tailed off, the facilitators (primarily the first two authors of this paper), in consultation with the delegates, grouped the concepts into clusters. In identifying clusters, attention was paid to those concepts which represented primary actions and policies, intermediate consequences or means to an end, and fundamental objectives. In all three workshops, no fundamental disagreements on the clusters or items to be included were evident, either between participants, or between participants and the research team present. In any case, the results (summarized in the form of the causal maps as discussed below) were reported back to the group later for confirmation.

The use of causal or cognitive maps for structuring problems prior to the application of MCDA has been discussed by various authors, e.g. Bana e Costa et al. (1999); Belton et al. (1997); Montibeller and Belton (2006), as well as in Belton and Stewart (2002, pp. 48–51). In our approach, the causal maps were prepared as a summary of the clusters identified as described in

the previous paragraph, i.e. as a summary of the outputs of the post-it sessions. In a sense, therefore, the maps served as basic documentation of the workshop results, and were fed back to participants at subsequent meetings for confirmation.

The maps did then also provide tools for analysis and reflection by the researchers. Key features, especially perceptions of goals and policy actions, of the problem structure could be identified (which were subsequently integrated across groups and fed back to each group for final comment). The maps were drawn using the Decision Explorer software (Banxia Software Ltd., Glasgow), which although designed primarily for cognitive mapping (see, for example, Eden and Ackermann, 2001), is well suited to our needs. It is, for example, easy to identify the "tails" (concepts with no incoming arcs, and which therefore may be associated with external driving forces and/or policy actions) and "heads" (concepts with no outgoing arcs, and which therefore may be associated with consequences perceived by the group to be of fundamental importance). This approach is illustrated in Figure 2, which is the causal map constructed from workshops with the Hawston community.

The central theme in the map of Figure 2 is probably that of concept 103, namely that the "wrong" people were receiving allocations of fishing rights, rather than the traditional fishing communities. Much of the remainder of the map provides an indication of perceived reasons for this theme, but the map also identifies a potential new course of action (concept 117) and some tentative objectives. Interpretation of the map is facilitated by classifying some of the numbered concepts under the following headings:

Driving forces: Concepts 101, 110, 112 and 115: These were viewed as the fundamental causes of the problems which were being experienced.

Policy proposals: Concept 117 introduced a proposal that was not part of current government policy at that time.

Goal-related issues: Concepts 107 and 120 are identified as "tails", and thus represent fundamental goals for the community. However, one needs to look further than only the explicit tails, as it may be that some concepts have a fundamental ultimate importance in their own right, even though they may peripherally also influence other concepts. On the basis of recorded discussions in the group, it was clear that such a situation applied to concepts 105 and 106. Concept 105 (increased crime and poaching) does have an effect on stock levels (concept 120), but was clearly primarily of direct fundamental concern. Similarly, concept 106 (community disintegration) does tend to aggravate crime

levels but had been stated in group discussions to be of key fundamental concern. From these considerations it was concluded that the primary goals as perceived by the community could be summarized as:

1. Elimination of poaching-related gangsterism and crime (concept 105), which is viewed to arise because the "true" fishermen were not receiving rights (concept 103);
2. Prevention of community disintegration (concept 106): The other links in the map suggest that the goal may be achieved by addressing the following issues, which may be viewed means-ends objectives in the sense of Keeney (1992):
   - Reduction in poverty;
   - Reduction in unemployment;
   - Fair division of rights across the community (cf. concept 108).
3. Improvement of health and living standards (concepts 107), which also seen to be driven by poverty levels.
4. Preservation of stocks (concept 120).

The causal maps are valuable as a problem structuring tool, but the development of a decision support system in an MCDA framework does require greater formality in identifying operationally meaningful criteria by which goal achievement (associated with specific rights allocations) can be measured, i.e. measures which are understandable to all participants and for which relevant data can be obtained within time and resource constraints. The last of the goals identified above, namely stock preservation, is addressed independently of the rights allocation process by the setting of the total allowable catch (TAC) for the fishery, and is thus not directly relevant to the decision support under discussion in the this paper. Thus, from the point of view of the Hawston community, the criteria relevant to allocation of rights are represented by concepts 105, 106, and 107, which may be viewed as components of a higher level fundamental objective of maintaining social continuity and integration.

For purposes of decision support system development, the fundamental objectives need to be unpacked into operationally meaningful measures according to which rights applications can be evaluated. This unpacking was formalized by construction of a *value tree*, i.e. a hierarchical representation of decision criteria against which applicants for rights allocations could be evaluated, which is illustrated in Figure 3 for the Hawston community. At

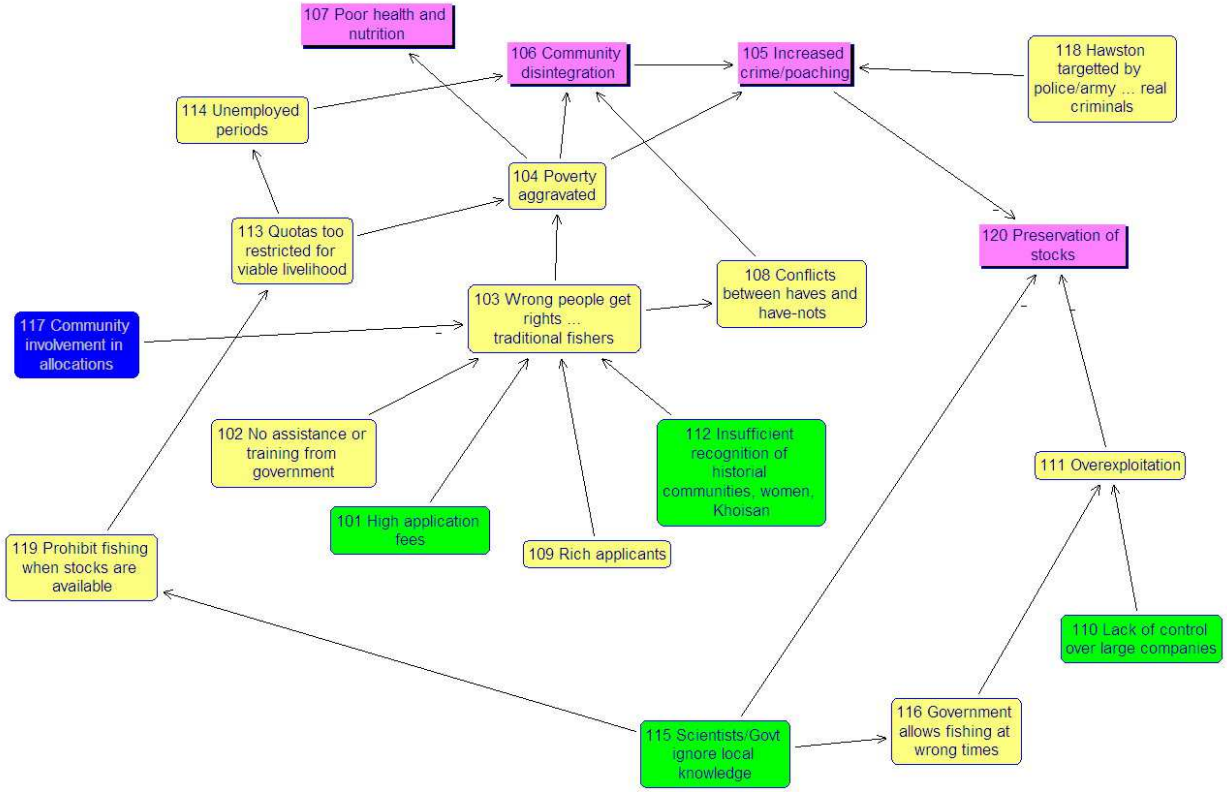

Figure 2: Causal Map from Hawston Workshops

the highest level in Figure 3, we have "social continuity and integration" as identified above from the relevant causal map. In order to decompose the highest level criterion into detailed and operationally meaningful subcriteria for evaluation purposes, it was necessary to return to the source documents from the workshop, namely the individual "post-its", and records kept of both the preliminary statements by the participants and subsequent discussions during the clustering process. In essence, from these notes and records we sought any mention of means to the fundamental end represented by the highest level criterion. Some of the relevant issues had been captured in the causal map (e.g. concepts 103, 108 and 113 which identify aspects of social continuity and integration), but further details needed to be extracted from the documents and were grouped as shown on the right hand side of the value tree in Figure 3. Once again, our summarized value tree was fed back to participants in subsequent meetings.

The grouping of the detailed subcriteria into the intermediate subcriteria shown in Figure 3 was carried out by the research team for ease of discussion and communication (but without effect on the final proposed decision support system). Three such intermediate subcriteria were identified in this way:

- *Direct links to the community*, with preference to those residence in the area and related to the need for recognizing historical communities (concept 112);

- *Fair distribution*, aimed at reducing conflict (concept 108), redressing past wrongs (with preference to "historically disadvantaged persons", or "HDPs") and ensuring viable livelihood (concept 113); note that, in contrast to more conventional identification of criteria in MCDA, important subcriteria included statements as to what should <u>not</u> be taken into consideration in allocating rights.

- *Dependence and involvement*, i.e. allocation of rights to those whose historical roots and livelihood depended on the fishery rather than new entrants (cf. concepts 112 and 117).

The above descriptions refer largely to the initial workshops. In the case of the Hermanus/Hawston group, a small number of delegates attended a follow-up workshop about two months later, for purposes of reviewing the results from the first workshop. It proved difficult to get the other two groups together in a similar way, but contacts were made with some spokespersons in the groups for review. Finally, all delegates were invited back to report-back meetings (one in Hermanus and one near Ocean View) after outputs

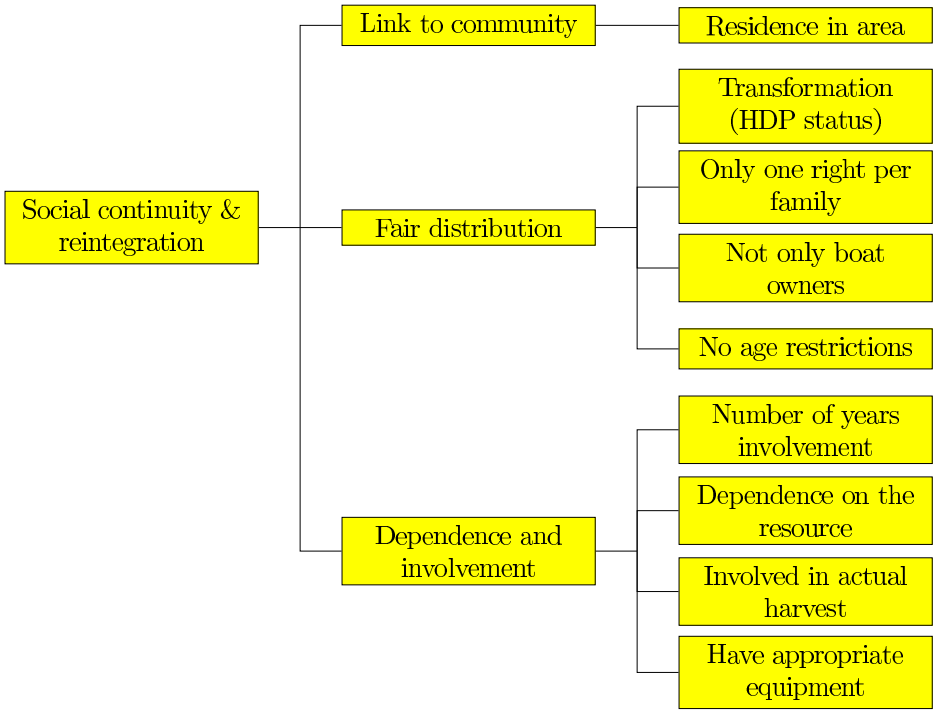

Figure 3: Value Tree for Hawston Community

from the three groups and from the state officials (see next Section) had been integrated. Delegates from Hawston/Hermanus and Ocean View attended these meetings, at which it was confirmed that the integrated value trees did not omit any issues of concern. It was at this stage that the delegates present were invited to suggest scoring systems for each criterion and relative weights for the criteria. We shall return to discussion of the outputs of these final meetings in Section 4.

Full details may be found in the full project report (Joubert et al., 2005), but it was found that the above process (from workshops to cognitive maps to value trees) led to the identification of essentially similar criteria in all three study frames. In fact, even the relative importance attached to each criterion which emerged from the final meetings was broadly consistent between the three groups (see Section 4). We concluded that the structure and discipline of MCDA thinking, combining "hard" and "soft" OR methods did provide a defensible framework for elicitation of the views and preferences of fishing communities.

3 Problem Structuring – State Level

By the time our project started, the state department (MCM) had already put a scoring system into place. After a pre-screening to remove those not satisfying certain minimum requirements, applicants for rights in a particular fishery were scored on a number of attributes, and these scores were tallied to provide a total score for the applicant. Rights were then to be granted to or withheld from applicants on the basis of these total scores. This process is effectively an additive value function approach. Although additive value functions can be a very valuable tool for multicriteria decision analysis, with the advantages of simplicity and transparency, there is an inevitable tension between the theoretical basis for validity of the additive model and the practical difficulties of verifying the required conditions. Such theoretical requirements include preferential independence of criteria and interval scale properties of the marginal value functions, as discussed in Belton and Stewart (2002, Section 4.2). In other work (e.g. Stewart, 1996) we have demonstrated some degree of robustness of additive models to moderate violations of the assumptions, but have at the same time shown that a point is reached where violations of preferential independence and the interval scale properties can render the conclusions of an additive model very nearly meaningless (with rank ordering no better than random selection). The onus is thus on the facilitator or analyst to exercise substantial caution in developing additive models to ensure at least that the these assumptions are not grossly violated (even if total verification is an impossible ideal). It was not clear that the developers of the original MCM model had put any effort into challenging the validity of the underlying assumptions of the additive model.

With the cooperation of MCM, we were given full access to the scoring applied in four distinct fisheries, namely hake deep sea trawl, the traditional line fishery, west coast rock lobster and abalone. These data were analyzed to assess levels of consistency in the scores allocated and the effective criteria used. Although the systems did add some rigour to previous processes, a number of flaws were identified. There were inconsistencies between fisheries and also between rights granted and scores allocated, which could not easily be explained by the legal discretion entrusted to the Deputy Director General and the Minister. In spite of these flaws, however, it was clear that such a scoring system could be made to work, and was by now familiar to the officials concerned, so that the primary thrust of our approach was to apply a formal value measurement approach to the development of an additive (multicriteria) value function for scoring purposes.

The analysis of the past allocation also identified a large number of criteria which were being taken into consideration. The criteria which were identified were tabled at discussions with senior officials and later a workshop involving some of those concerned directly with the rights allocation process. These meetings generated some refinements to the sets of criteria which had emerged from the historical analysis, but led largely to an acceptance to the aggregate set of criteria which is discussed in the next Section (see Figure 4). Qualitative indications were obtained concerning the relative importance of the criteria, but it was clear that the relative importances would vary from fishery to fishery and also from year to year (as political priorities changed), and that there was some reluctance to commit to specific quantitative importance weights.

What emerged at this stage, therefore, was that a decision support structure could be set up for systematic use across all fisheries and for a period of time, but that precise scoring of applicants in terms of contribution to goals, and the relative weighting applied to these scores would need to be determined in each instance by the responsible resource managers (and ultimately the Minister). Nevertheless, a fixed structure would aid transparency and consistency of the process, and this became the primary aim of the remainder of our research.

4 Synthesizing the MCDA Structure

As discussed in the previous Section, the value tree displayed in Figure 4 was developed initially as a summary of the objectives hierarchy of the chief-directorate of Marine and Coastal Management. On the other hand, comparison of this value tree with those developed for the communities (as illustrated in Figure 3) showed no major omissions. The objectives of the communities related very much to historical involvement in the fishery, dependence on the fishery for subsistence and living, and links of the applicant to traditional fishing communities, all of which are incorporated into the integrated value tree of Figure 4. The integrated value tree was reflected back to the fishing communities and MCM at final workshops, and no substantial objections were raised.

Nevertheless, the integrated value tree did contain certain objectives at the MCM level which were more aligned with broader national goals than with the more localized goals of the communities. Two potentially controversial aspects emerging from the value tree were the following:

- An emphasis on the long-term commercial viability of the fishing in-

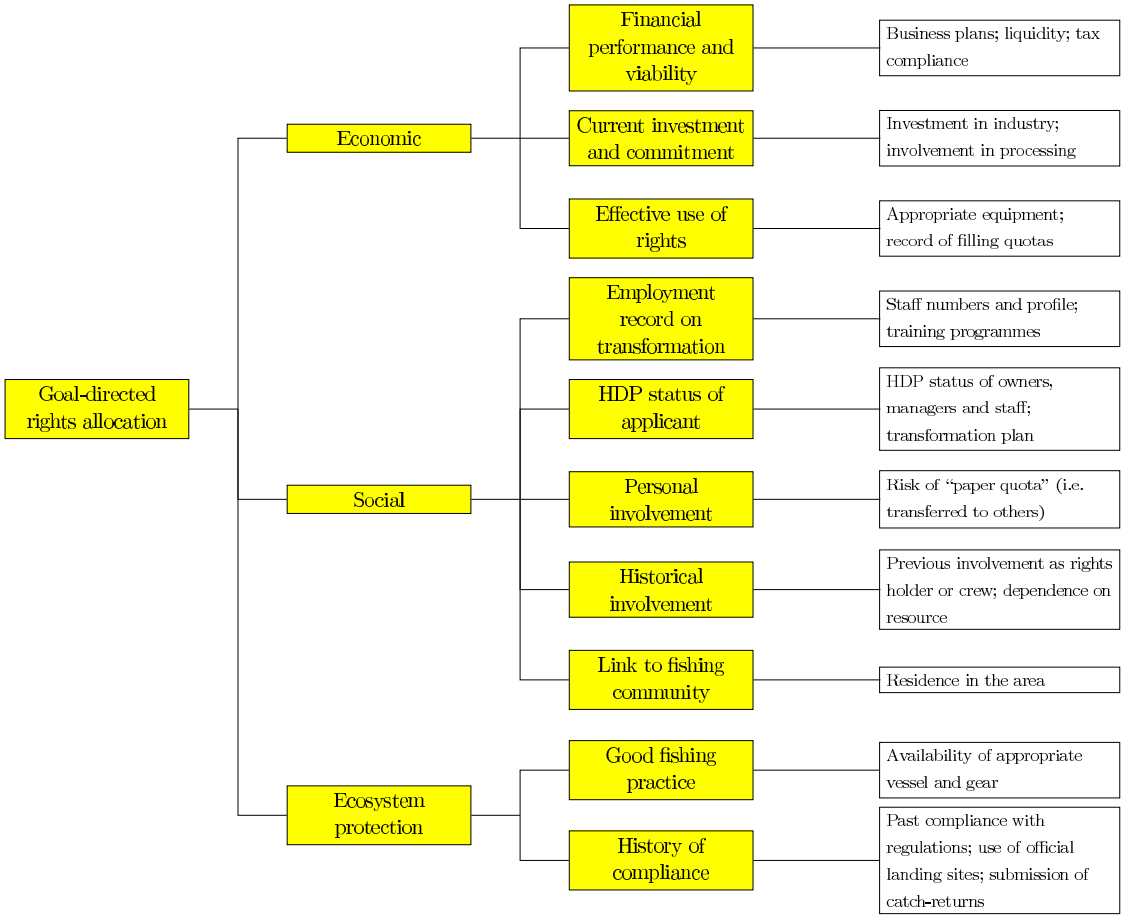

Figure 4: Integrated Value Tree for Fisheries Rights Allocations

dustry: This suggested a need for higher levels of management and financial skills than many in the community might possess, so that the interests of long-term commercialization might not coincide with the maintenance of a subsistence-level fishing industry.

- A broader definition of "transformation" in the industry: While the communities perceived transformation primarily in terms of a return of rights to traditional fishers, the state appeared to be seeking a demographic profile of participants in the industry that more closely represented the national demographic profile.

The shaded parts of the value tree in Figure 4 indicate the criteria in generic terms. The degree to which each applicant satisfies these criteria would require some judgement on the part of the management of MCM. The unshaded blocks indicate *some* key issues that would need to be taken into account in exercising such judgement.

The scoring system built into any decision support system such as that described below would also require specification of importance weights in the criteria used. The MCM represented the essentially final decision making authority, and would be responsible for any final implementation of the scoring system. MCM would need to be able to defend their weights at the time allocations are made, but they indicated that they did not wish to publish such weights prior to any specific allocation. In spite of the fact that the weights are ultimately the concern of MCM only, it seemed important to be able to obtain a prior assessment of importance weights as perceived by the fishing communities themselves, which could serve as important inputs into the final MCM process.

The principles underlying the meaning of weights in an additive value measurement approach are well-established. See, for example, Belton and Stewart (2002, Section 5.4) for an outline of these principles. An important feature is that the weights should reflect trade-offs over the ranges of values under consideration for each criterion. This implies that weights for use in an additive model need to reflect the importance of the "swing" from best to worst outcomes under consideration (e.g., von Winterfeldt and Edwards, 1986, Chapter 8). Thus, even for purposes of guideline inputs to the MCM process, it is important that any measures of importance elicited from the fishing communities should be informed by considerations of the underlying "swings". In view of the low levels of formal education amongst many in the fishing community representatives, it was also important to keep the process simple. During the final meetings with the communities in two of the study frames (Hawston and Ocean View, as the Kalk Bay group

were not available at this time), we consciously attempted through informal discussion with community representatives to get them to think about the ranges of possible outcomes (i.e. the "swings") that would apply. With the background of this common understanding, participants were then provided with fixed numbers of coloured stickers which they could paste against the criteria identified in the value tree, to indicate how the overall importance should be split between these criteria.

The weights allocated to the main groups of criteria, as assessed independently by the two groups (see Joubert et al., 2005, Chapter 5), were substantially similar. Although no absolute guarantee of validity, this correspondence at least satisfies the necessary condition for between-group validation of the consistency of the procedure. It is interesting to comment that this process demonstrates how simple and unsophisticated procedures can nevertheless be formally correct in the sense of consistency with underlying axiomatic assumptions.

In spite of the seemingly substantial correspondence between the goals of communities and of MCM, a high level of distrust was still expressed by the communities. The question then arises as to why there should be such dissatisfaction when the apparent goals were essentially the same. Further unpacking of the inputs from both groups suggested the following potential points of conflict:

- Complexity of process: MCM insisted that the process needed to allow for careful auditing and the identification of false claims made by applicants, and that this necessitated a comprehensive and detailed application procedure. However, the complications of the resulting process were seen by the communities as discriminating against the educationally disadvantaged (who struggled to complete the necessary forms) and against the poor (who could not afford the non-refundable deposits to cover the cost of processing).

- Existence of the additional goals of MCM (as indicated above): Clearly, any emphasis on seeking better achievement of the goals specific to MCM (i.e. sustainability and broader transformation) must lead to lower achievement of the shared goals.

At this stage it must be recognized that the final decision is not taken by a group, but is ultimately the responsibility of the Minister of Environmental Affairs & Tourism. The Minister delegates to MCM the responsibility to administer a process which leads to a final recommendation for approval. This process is fully managed by MCM and it can thus be argued that the

final decision is not a "group decision". Nevertheless, it is in the interests of MCM (and the Minister) to ensure as a broad a level of consensus from the relevant stakeholder groups concerning the process to be adopted. It is for this purpose that we adopted a group decision and negotiation *framework* for seeking such consensus. The levels of distrust from the fishing communities on which we have reported was at least in part a result of a perception that the previous processes were not transparent and did not include decision criteria of importance to the communities.

The process which we adopted did identify the criteria deemed to be important to each of the three communities when setting up the allocation process. They broadly accepted the principle of scoring applicants in some simple transparent manner, based on these criteria. MCM could thus move forward to establishment of the administration of the scoring processes, with confidence that they had not overlooked serious concerns emerging from the communities. In the final meetings with the fishing communities, the delegates expressed satisfaction that the process we had established did indeed capture their views and objectives. It is true that the aggregate value tree of Figure 4 did include additional criteria beyond those emerging from the group processes. Such additional criteria are within the rights and responsibility of the Minister and his Department (representing broader national interests). No major objections to the any of the criteria displayed in Figure 4 were voiced at the final meetings, although their existence certainly leaves potential for later objections from the communities. It is precisely the process which we adopted, however, that warns MCM and the Minister of such potential as they implement a final evaluation system.

In aiding the setting up of an administrative process which integrates the group goals and aspirations, the challenge to the decision scientist is to design a decision support system that:

- Provides a simple but coherent system that can be used by fisheries managers in a consistent manner across all fisheries and categories of applicants; and

- Is transparent and auditable in the sense of demonstrating that all goals have been taken into account and recording value judgements made.

A proposed outline of such a system is described in the next Section.

5 Design of a Decision Support System Template

The purpose of the DSS described in this section is then to provide the simple coherent system for capturing relevant details of the applicants for fisheries rights, and for facilitating the allocation of these rights in a goal-directed manner, i.e. in a manner which is in alignment with the accepted management goals. The process of rights allocation includes two distinct *problematiques* in the sense of Roy (1996, Chapter 6), namely both a *ranking* and a *sorting* (classification) problematique. In other words, the DSS needs to recognize and to support a two-stage process, first a simple *ranking* of applicants followed by a *classification* of applicants into those receiving or not receiving rights. We describe first a basic system for implementing a value scoring system, and then an extension to this system in which goals related to rate of transformation are dealt with separately from scoring of applicants on an individual basis. Finally, the user interfaces for the DSS are briefly described.

5.1 Value Scoring System

As argued earlier, the fact that the MCM management had been using a simple additive scoring system led us to conclude that the implementation of an additive value function model might be the most acceptable approach, while also being simple and transparent. In other words, a goal achievement score, say V_k, would be associated with applicant k (within a particular fishery and category of licence), defined by:

$$V_k = \sum_{i=1}^{p} w_i v_{ik} \tag{1}$$

where:

v_{ik} = The score allocated to applicant k in terms of criterion i
w_i = The relative importance weight associated with achievement of criterion i
p = The number of criteria being used for evaluation

The assumptions underlying and validating the use of an additive value function model such as (1) have been documented elsewhere (e.g., Belton and Stewart, 2002, Section 4.2 and Chapter 5). In principle, support needs to be provided for the following three stages.

1. *Selection of criteria:* The criteria should be complete and preferentially independent in the sense that relative values of incremental gains within one criterion, or tradeoffs between two criteria, can be elicited without needing to consider performance on other criteria. Total verification of preferential independence is a challenging process, even for single decision makers (as pointed out by a referee). We have earlier commented on the robustness of additive models to moderate violations of the assumptions. As a plausibility check for substantial violations of preferential independence, we did ask participants to think about how one would recognize good performance on each criterion in isolation. In no case did anyone raise difficulties relating to a need to score performance on one criterion differently for different levels of performance on other criteria.

   The criteria in Figure 4 were established through many rounds of discussion with a number of groups, so that it is unlikely that there exist objectives of importance to any stakeholder group that are not captured there. It is possible that in any particular fishery and/or category of applicant that not all of these criteria will be value-relevant, however. A decision support template should therefore include all of the criteria from Figure 4, but allow the user (manager) to select only a subset of these. Naturally, reasons for excluding certain criteria would need to be documented clearly for purpose of auditing.

2. *Scoring of levels of achievement on each selected criterion (v_{ik}):* Space needs to be provided for a clear operational definition (often verbal) of 3–7 levels of performance or achievement for each criterion selected. This ensures clarity on what is intended by the relevant criterion, and is thus subject to audit assessment regarding consistency of application. At the same time, scores should be allocated to each level defined in this way. For ease of interpretation of weights (see next point), it is useful to use a common scale definition across all criteria (e.g. 0–100 can work well in cultures familiar with a percentage as a measure of achievement, with the weakest performance level scored at 0, and the best at 100). However the scales are defined, the attention of users needs to directed towards comparison of the relative importance of the value "gaps" between successive levels, an important consideration in ensuring that the resultant scales are of the interval nature defined by the model.

3. *Specification of weights (w_i):* Guidance needs to be provided to users

to focus on the range of performance levels implicit in the operational definitions for each criterion (corresponding to the "swing weighting" interpretation implied by (1)).

The outline template described in subsection 5.3 does illustrate a means by which the above functions can be supported in a simple spreadsheet-based manner.

5.2 Mathematical Programming Extension

For most of the criteria identified in Figure 4, it is possible to obtain a score for any one applicant without reference to other applicants. This property facilitates transparency, as each applicant can directly verify their own scores, even though the final rankings and allocations will of course go to those with the highest scores. It is also meaningful to declare weights for each criterion, as these will simply reflect value tradeoffs between the criteria.

The situation is, however, somewhat more complex in the case of the "transformation" goals, i.e. the correction of past inequities. Goal achievement in terms of these criteria needs to be measured by the proportions of those allocated fishing rights who belong to designated groups. The "score" allocated to an individual applicant will have to depend of the group memberships of other groups. In fact, scores and/or weights for these criteria need to be adjusted after all applications are in, in order to achieve the desired level of transformation. This fact conflicts with the need for transparency and is easily subject to criticism of manipulation of the process. One could further question whether a purely additive model such as (1) can be justified in this case.

An alternative proposal is to apply an additive model only to those criteria for which a direct scoring is possible for each individual independently of other applicants. This model could provide an aggregate value score to each applicant, on the basis of which applicants could be rank-ordered before consideration of transformation goals. We then introduce a simple integer linear programming model to select the set of applicants having the highest total of the additively aggregated scores, subject to not exceeding total allowable fishing effort and to satisfaction of the group membership goals.

Formally, suppose that a number $q < p$ of the criteria are directly and individually related to the applicant so that performance in terms of these criteria can be assessed independently for each applicant, justifying use of an additive value model for aggregation across these criteria. The remaining

criteria, labelled $q+1,\ldots,p$ then relate to desired participation levels for designated groups. Now for $i = q+1,\ldots,p$ define the following:

a_{ik}: Parameter taking on the value 1 if applicant k belongs to the designated group associated with criterion i (and 0 otherwise)

A_i: Desired minimum proportion of rights holders which should come from the designated group

z_k: Binary variable taking on the value 1 if applicant k receives a rights allocation (and 0 otherwise)

N: Total number of applicants within the relevant fishery and category

T: Maximum number of rights which can be allocated in order not to exceed the total allowable catch (TAC)

The following integer linear programming problem then finds the allocation which maximizes total aggregate value for criteria other than transformation targets, subject to achieving the desired levels of transformation and to the constraint on the maximum number of rights:

$$\left.\begin{array}{lrcl} \text{Maximize} & \sum_{k=1}^{N}\sum_{i=1}^{q} w_i v_{ik} z_k & & \\ \text{subject to:} & & & \\ & \sum_{k=1}^{N} a_{ik} z_k & \geq A_i \sum_{k=1}^{N} z_k & \text{for } i = q+1,\ldots,p \\ & \sum_{k=1}^{N} z_k & \leq T & \\ & z_k & \in \{0;1\} & \text{for } k = 1,\ldots,N \end{array}\right\} \quad (2)$$

In the decision support system template (see subsection 5.3), the optimization model was referred to as a "goal program" for purposes of presentation to clients (emphasizing the focus on achieving transformation goals), even though (2) is not a goal programing model in the usual sense.

The combination of a directly verifiable additive score and openly declared transformation goals would seem to associate a desirable level of transparency with the process. When the model given by (2) was presented to MCM management, however, they appeared wary of committing themselves openly to specific target proportions A_i, although they did see value in carrying out *what if* analyses in-house. The approach was thus included in the decision support template, allowing them to experiment with different target proportions as comparison with those generated by the partial scores v_{ik}. As indicated earlier, from a value measurement perspective there are theoretical problems around extending the scoring system to the transformation target criteria, so that the above optimization model seems to offer a more justifiable approach on theoretical if not always on political grounds.

5.3 DSS User Interface

There are no substantial difficulties in providing support for the above functions directly in a spreadsheet template. A prototype version of the DSS was developed in *Microsoft Excel* and demonstrated to officials from MCM.

Four basic functions need to be provided, as indicated by the main buttons on the user interface illustrated in Figure 5, namely selection and operational definition of criteria to be used, entry and editing of applicant data, scoring and ranking of applicants and analysis of results which includes the mathematical programming model.

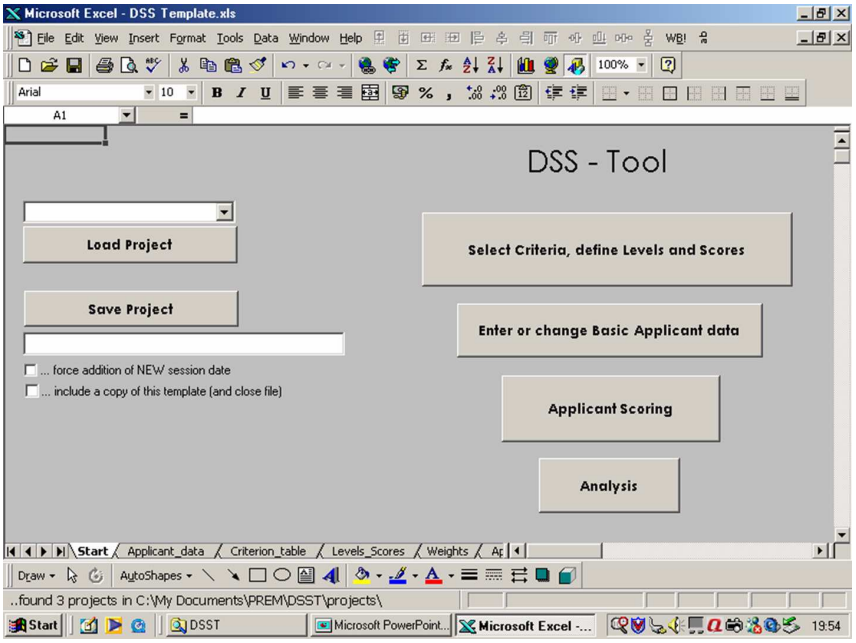

Figure 5: Main user interface for the DSS template

- The selection of criteria is done by selection from drop down lists, as illustrated by the screen displayed in Figure 6. The definitions for levels of performance in terms of each criterion, and scoring of these levels are guided by the screens illustrated in Figure 7. Both the scoring and weighting operations can further be guided by simple documentation setting out the principles described in subsection 5.1.

- Entry and editing of input data are carried out in standard spreadsheet mode.
- Scoring of applicants, and ranking according to the scores are achieved by simple and quite standard macros.
- The analysis button in the main screen (Figure 5) provides various graphical displays (e.g. bar graphs of the scores for accepted and rejected applicants), and also for the solution of the linear programming models (2) for various target proportions.

Further details are given in the full project report (Joubert et al., 2005) which is available on the web (www.premonline.nl), or from the authors on request.

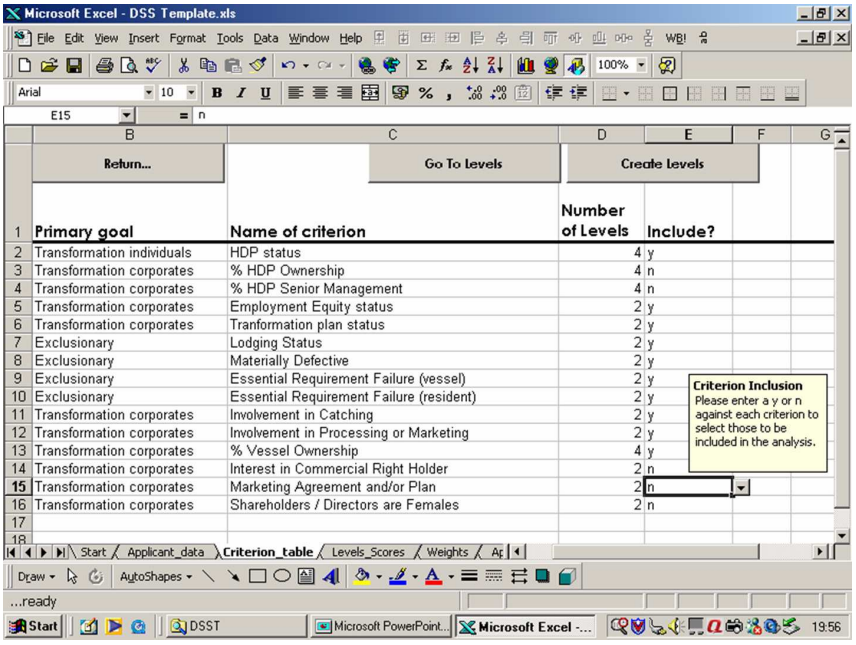

Figure 6: User interface for selecting criteria

6 Conclusions

As indicated in the introduction, the work that has been described here was in the first instance describable as *action research*. The project team

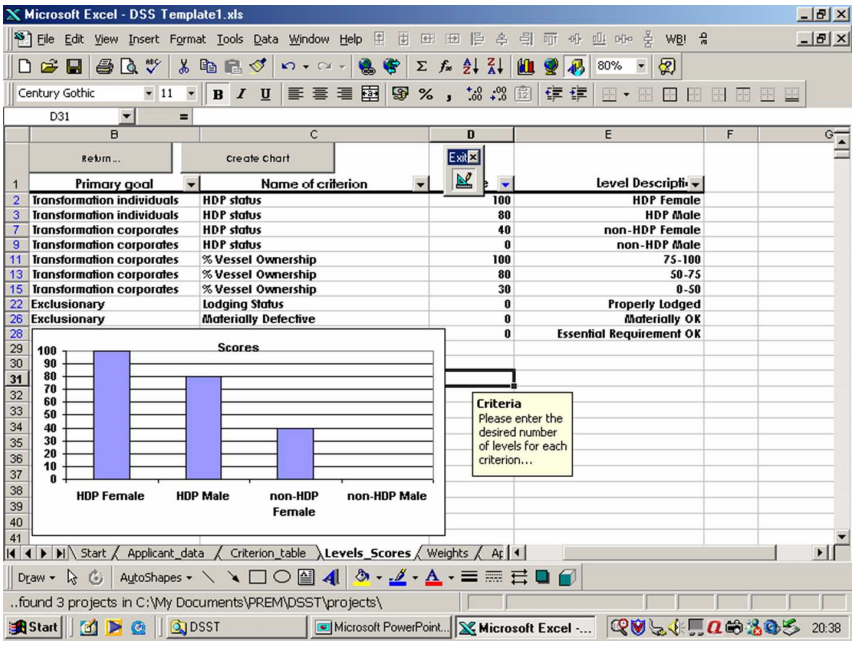

Figure 7: User interface for scoring criteria

immersed themselves in the real issues facing both the fishing communities and the responsible government department, and sought to work with these groups in seeking workable solutions.

Nevertheless, we reflected back consciously on the experiences gained through nearly 18 months of involvement. Although no two problem settings of this nature are ever completely alike, this reflection did generate conclusions concerning the methodology which appear to be generalizable. Some of these conclusions do support proposals made elsewhere, but little seems to have been reported in the literature on experiences from action research similar to that reported here. These conclusions relate to MCDA as a vehicle for creating a problem structure that can be communicated between groups, the value of causal mapping as a means to extracting decision objectives, and the applicability of the process to problems involving highly divergent groups, some involving stakeholders who may be functionally illiterate. We elaborate on each of these points in the following.

1. The benefit of using causal maps as means to capturing information from a wide range of stakeholders, and as a means to construct value

trees, has been demonstrated. Identification of "tails" and "heads" in the maps lead naturally to discovery of perceived driving forces and of criteria for evaluation of policy. The fact that the value trees and associated weighting of criteria emerging from workshops with different fishing communities demonstrated a high level of consistency is at least *prima facie* evidence for the validity of this part of the process.

2. The multicriteria decision analysis (MCDA) framework in which problems are structured in terms of clearly defined actions and goals provided a valuable vehicle for communication between stakeholders, especially within the context of a situation in which antagonism between groups prevented joint workshops (all stakeholders together). In spite of the strong antagonism which had existed, all groups came to accept the basic structure of the resulting composite value tree.

3. Essentially the same process, from original workshops, through causal maps and on to formal MCDA structures was demonstrated to be applicable to widely diverse groups, differing also widely in terms of formal education levels (from marine scientists to barely literate or even functionally illiterate members of the fishing communities).

A further important advantage to using formal MCDA as the problem structuring process was that this approach allowed the outputs from interaction with stakeholders to feed directly and immediately into the design of a DSS.

Since the work described in this paper, MCM have implemented a considerably more complex system than that proposed here, and it seems that this system lacks transparency to many applicant groups. The criteria taken into consideration do not differ substantially from those displayed in Figure 4. The methods of scoring applicants in terms of these criteria, however, follows a complicated process (based on percentiles of the distribution of inputs from all applicants) that in our view violates the value measurement principles underlying an additive scoring system, and can be highly sensitive to data input errors. Once again, as happened with previous allocations, the allocations made according to the 2006 system were subject to challenge in the courts. The original intention had been for the 2006 allocations to be made for 10 years, but in view of the court challenges it is possible that some allocations may need to be revisited and we remain hopeful that some of the suggestions above might be included in a revised process.

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