ORiON, Vol. 8, No. 2, pp. 54-68 ISSN 0259-191-X

WILDLIFE MANAGEMENT USING THE AHP

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ABSTRACT

Two applications of Saaty's Analytic Hierarchy Process towards solving decision problems in Wildlife Management are discussed. The first involves structuring the management objectives of a National Park and establishing priorities for the implementation of various possible strategic management plans in the Park. The second deals with the problem faced by the various non–governmental organisations concerned with the conservation of the Rhino and Elephant populations in Southern Africa, of deciding how best to allocate their funds towards this purpose. General conclusions are drawn concerning the use of analytical techniques, particularly the AHP, in planning and decision making in Wildlife Management.

1. INTRODUCTION

The Conservation and management of the World's remaining populations of wildlife species is a matter of grave concern, not only to biologists and wildlife managers, but to Humanity as a whole. The wholesale slaughter of wildlife that has been taking place in Africa over the past century and more, but particularly during the last decade (Rosenblum and Williamson [14]), is a great tragedy which threatens the survival of many species unique to Africa.

One way of ensuring the survival of wildlife in the modern world, including the habitats in which they thrive, is to set aside large tracts of land in which the animals are allowed to roam relatively undisturbed, and where Man's role is subservient to that of the animals. However, these national parks and other wildlife reserves are complex systems that require management in order to ensure their survival. Moreover, with the continuing pressure which development and population growth is putting on the land, the managers of these reserves will increasingly have to be concerned, not only with biological and ecological considerations, but also with their financial and political viability.

Traditionally, the management of these reserves has been the preserve of managers trained in the biological sciences, but the complexity of the systems they are trying to manage make this a fertile area for the application of OR techniques. In recent years there has been an increasing interest by the OR community, particularly in South Africa, to become involved in tackling problems in this area. These include systems dynamics models to assist managers in establishing culling and translocation policies for their parks, as well as to help understand the dynamics of predator–prey systems, multiple criteria linear programming to assist in deciding on the optimal 'mix' of animals in a national park, and many others (Starfield & Bleloch [21]). Fatti [5] describes some OR applications to South African Wildlife problems.

Saaty's Analytic Hierarchy Process (AHP) has been widely used for structuring planning and decision problems, and for eliciting priorities or preferences in complex situations where several criteria may pertain, and where conflict may exist between interested parties. Good descriptions of the AHP and its application to such problems appear in Saaty [15], [16], Golden et al [10] and in many other texts. Applications in the South African context are given by Saaty [18], Fatti and Stadler [7] and Fatti [6].

There has been much controversy in the literature on the validity of aspects of the AHP as a multi–criteria decision making tool. (Belton and Gear [2], Saaty and Vargas [20], Belton [1], Saaty [17], Harker and Vargas [11], Islei and Lockett [13], Dyer [4] and

Harker and Vargas [12]). The decision to use the AHP in the decision problems described in this paper was based on the author's success in applying it in environments where the participants had little or no experience in Operations Research or Decision technology. (See, for example, Fatti, [6]) In the author's experience, the hierarchical structuring of the decision problem, inherent in (but unique to) the AHP, appeals to participants, as does the method of pairwise comparisons, implemented for group decision making, and its associated measure of internal consistency. Whether this is sufficient justification for using the AHP, despite the controversy is a moot point, and depends on where one stands relative to the different arguments put forward by the various authors. The incontrovertible fact is that in both applications described in this paper the participants were quite happy with the process of establishing priorities, and accepted the results as a reasonable reflection of their intuitive feelings. Furthermore, since the purpose of both exercises was "insight, not numbers", a high degree of accuracy in the final priorities was not of importance.

This paper describes two applications of the AHP towards solving decision problems in Wildlife Management. The first application is that of structuring the management objectives of a National Park and of estabishing priorities for the implementation of various possible strategic management plans. The second is concerned with assisting various non–governmental organisations in deciding how best to allocate their funds towards the conservation of the Rhino and Elephant populations of Southern Africa.

2. MANAGEMENT OBJECTIVES OF A NATIONAL PARK

The Pilanesberg National Park is Bophutatswana's largest game reserve and the fourth largest game reserve South of the Limpopo River. Comprising 500 square kilometers, it contains some 8000 head of game, ranging from Elephant and Rhino to many species of antelope, as well as predators such as leopard and cheetah. It also plays an important role in the conservation of rare and endangered species, such as tsessebe and sable antelope as well as rare birds and plants.

The Park has a network of tourist roads and camps with facilities ranging from luxury chalets to tented accomodation, campsites and dormitory accomodation for school children. It plays an important role in conservation education in Bophutatswana and many school groups visiting the park make use of the education and information centre located within the Park. A number of places of historic interest are preserved within the boundaries of the park, and members of the the Bakgatla tribe, original inhabitants of the area, are allowed to continue with some of their traditional uses there, such as visiting ancestral sites and collecting medicinal herbs and plants. This tribe also benefits from the meat obtained from periodic culling operations within the park.

Since its inception, the management and board of control of the park have realised that in order to survive, not only must its importance be appreciated by the politicians of the day, but it must also not place too heavy a financial burden on the state. Thus an important management goal is to attain economic self–sufficiency in the forseeable future. To this end the management took the controversial step a few years ago of introducing commercial trophy hunting in certain areas of the park not visited by tourists. Today this activity provides one of the most important sources of revenue for the park.

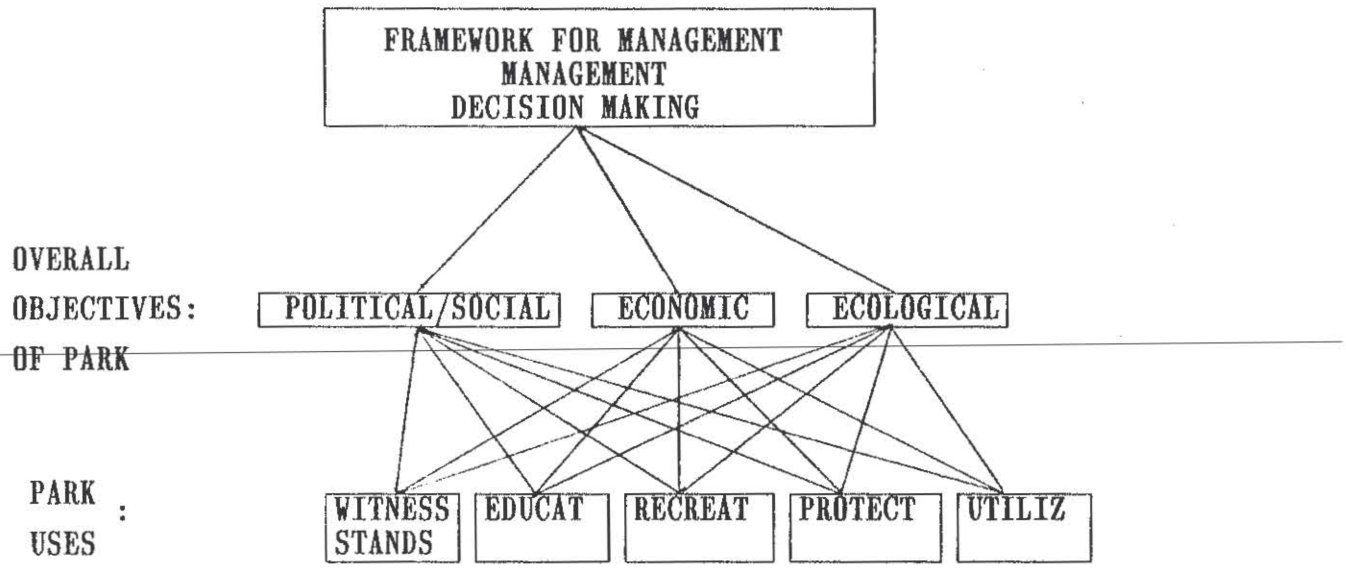
In May, 1986, the author was invited to join a two–day workshop held at the Pilanesberg National Park with the aim of assisting in establishing objectives for the management of the park. The intention was for this to be the first phase towards setting up a management planning system for the park, which could serve as a model for Southern African game reserves in general. At a meeting with the organisers beforehand, it was decided to use the AHP as the framework for conducting the workshop, and a preliminary hierarchy was set up to serve as a starting point for discussions.

Apart from the author and a computing assistant, all of the approximately fifteen participants at the workshop were wildlife managers or scientists concerned with wildlife management. Although most of them had no experience of the AHP, nor of OR in general, it did not take them long to become familiar with the concepts once they had been explained with the help of a simple example. Most of the first day was spent debating about the structure and components of the hierarchy of objectives, and the one finally agreed upon is presented in Figure 1. The participants recognised that the uses of the park had their ecological, as well as economic and political/social aspects, and that all management decisions and activities should be seen in the light of these three main components.

The author acted as group leader and facilitator for both the hierarchical structuring and the pairwise comparisons phases of the exercise. Great care was taken to ensure that there was agreement amongst the participants as to the precise meaning of the various components of the hierarchy, in particular the three main components comprising the overall objective of the park, prior to establishing priorities amongst them. These three components were prioritised first, and at the end of the whole exercise the group reconsidered them to ensure that they still reflected their priorities, seen in the light of the different park uses.

Figure 1

MANAGEMENT OBJECTIVES FOR A NATIONAL PARK



POSSIBLE	BUILD MORE ROADS
MANAGEMENT :	BUILD MORE EDUCATIONAL FACILITIES
ACTIVITIES	INTRODUCE MORE GAME SPECIES
	INTRODUCE LION
	. . . .
	. . . .

In order to establish priorities for the three main components of the hierarchy and for the various uses of the park, the Delphi–type method described by Fatti [6] was used to achieve consensus amongst the participants on the various pairwise comparisons required by the AHP. Briefly, for each comparson, this method entails obtaining anonymous responses from all participants, which are then summarised by means of a histogram and geometric mean, and presented to the group. After a discussion, participants have the opportunity to modify their judgements, and when the group is satisfied that the spread of opinions is acceptably low, the geometric mean of the final set of judgements is used as the consensus figure. Group participation and feedback was achieved by projecting the images from the PC software "Expert Choice "(Forman and Saaty [8]) and the histogram program (Clarke [3]) onto a screen where the results of their judgements could be clearly seen. It has been the author's experience that this method tends to produce very consistent pairwise comparisons matrices, despite the subjectivity of the participants' decision as to when to accept the geometric mean as their consensus judgement.

The pairwise comparisons matrix for the three overall objectives of the park, obtained from the participants in the above manner, are given in Table 1, together with the priorities and inconsistency ratio estimated by the Eigenvector method Saaty [15].

Table 1

Pairwise comparisons matrix and priorities of the three overall objectives of the park

	Political/ Social	Economic	Ecological	Priorities
Political/ Social	1,0	2,0	1/1,3	0,374
Economic		1,0	1/1,4	0,230
Ecological			1,0	0,396

Inconsistency Ratio: 3,7%

It is interesting to note that while ostensibly the objective of a game reserve should be the conservation of animal species and their habitat, the "Political/Social objective was considered to be virtually as important as the "Ecological" objective. This is a reflection of the realisation amongst the participants, all of them wildlife managers or scientists, that in order to survive in a developing African region, the park had to be seen by both the local inhabitants and the politicians as being important to them.

The five different park uses were then compared, separately with respect to each of these three park uses, yielding the priorities in Table 2.

Table 2

Priorities for the Pilanesberg National Park

Overall Objectives:	Political/ Social	Economic	Ecological	Overall
Priorities:	0,374	0,230	0,396	1,000
Uses of the Park	Priorities with respect to each objective			
Witness Stands	0,036	0,039	0,409	0,185
Education	0,285	0,076	0,113	0,169
Recreation	0,419	0,499	0,053	0,292
Protection	0,093	0,068	0,287	0,164
Utilization	0,166	0,317	0,139	0,190

In the light of the importance assigned to both the Political/Social and Economic objectives of the Park, and noting that "Recreation" was rated as the most important use for both of them (whereas it is of little value from a purely ecological viewpoint) it is not surprising that this comes out as the most important use of the park. This is followed by "Utilization" (trophy hunting, meat sales, etc) while the two purely conservation uses of the park, namely "Witness Stands" (the conservation of important habitat types) and "Protection" come lower down on the list.

It is interesting to note that with respect to both the "Political/Social" and the "Economic" objectives of the park, the relative weights of "Recreation" and "Witness Stands" exceed the maximum ratio of 9:1 which is possible in Saaty's 9–point scale for individual pairwise comparisons. This is a reflection both of the fact that the participants rated "Witness Stands" very low relative to the other uses when considering these two objectives (in contrast to the "Ecological" objective, where this use is rated top) and possibly also of the tendency of Saaty's eigenvector method to produce results outside this maximum ratio, as reported by Islei and Lockett [13].

Although the workshop did not take the exercise any further, it laid the framework for the evaluation of the various, possibly competing, management activities in the park, such as building more roads or introducing more animal species. Specifically, the idea would be to consider the set of possible activities as the next level in the decision hierarchy, for which importances would be established relative to each of the park uses. These would then be weighted by the priorities of the uses to obtain their overall priorities. Note that, since the set of possible alternative activities was not identified at the workshop, an absolute measurement scale, such as that described in the next section, should be used to assess the importances of the different activities relative to each of the park uses. This will avoid range effects, as well as the possibility of rank reversal occurring when more alternatives are introduced at a later stage (Saaty [19]). Note that, since the relative importances of the different overall objectives of the park have already been taken into account in establishing the priorities of the different park uses, they do not have to be taken into consideration when establising priorities for the various management activities.

The priorities of the various possible management activities can be used in different ways. These can range from selecting those activities with the highest priorities for immediate implementation and shelving the rest; using the priorities to select a short list of activities from which those for immediate implementation are chosen according to criteria other than those used in the hierarchy; to using the priorities in the objective function of a knapsack algorithm for selecting the 'best' subset of activities to implement, subject to one or more resource constraints.

An encouraging outcome of the exercise was the enthusiasm which the participants displayed towards the approach adopted by the workshop, and they were generally in agreement that it would be of value for strategic planning, not only in the Pilanesberg National Park, but also in the other game reserves of Southern Africa.

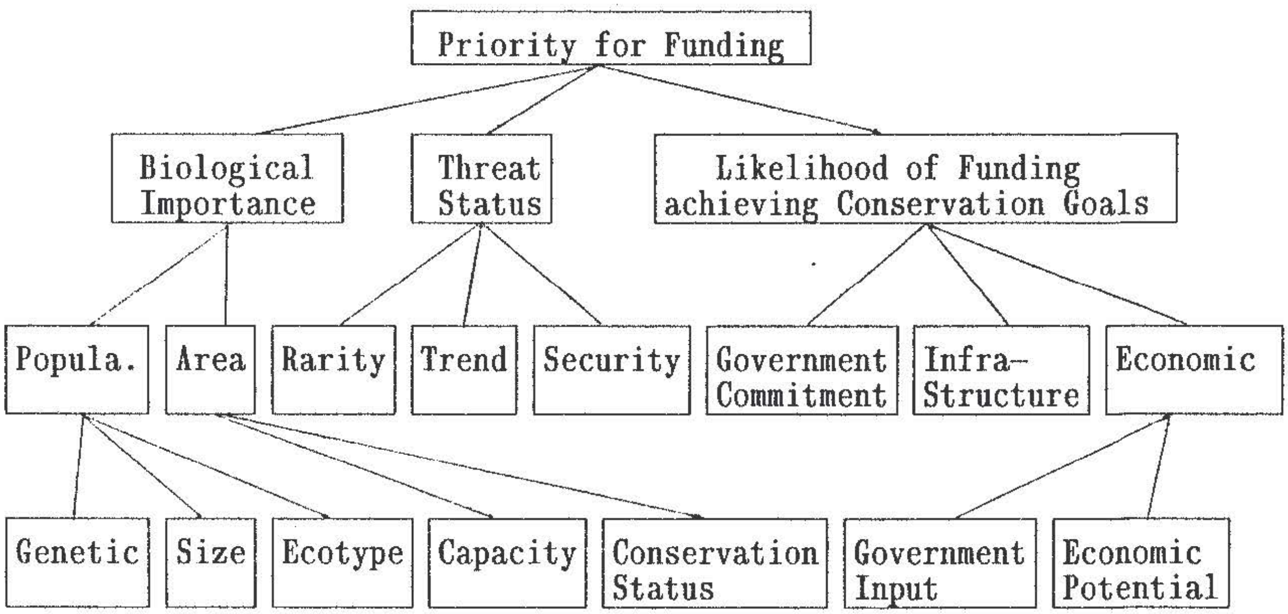
3. CONSERVATION OF RHINO AND ELEPHANT

In response to the outcry over the wholesale slaughter of rhino and elephant in Africa, particularly over the last decade, a number of non–governmental conservation organisations (NGO's) have started to raise funds towards conserving the remaining populations of these large mammal species in Southern Africa. Having raised the funds, they are then faced with the difficult problem of deciding how best to allocate them towards achieving their stated purpose. All too often NGO's tend to be influenced by emotional factors and public sentiment when choosing projects to fund, rather than by careful consideration of the various criteria relevant to the conservation of these species. Not only is it important to consider the biological value of the population and its conservation status when deciding whether or not to allocate funds to it, it is also essential to take into account the likelihood of funding achieving its conservation goals.

In May 1989 two senior conservationists, concerned about this problem and about the possible conflict between rival conservation organisations in allocating their funds, arranged a two–day workshop in the Kruger National Park to discuss the matter, and invited representatives of the various NGO's as well as of the official conservation bodies in Southern Africa to attend. The author was again invited to provide a structure for the workshop, and after some preliminary meetings with the organisers it was decided to use the AHP for the purpose.

At the start of the workshop the participants were presented with a preliminary hierarchy, and after a great debate it was agreed that the modified hierarchy in Figure 2 best represented the structure of the decision problem:

Figure 2



The participants also agreed to use the same hierarchy for the three species (Elephant, Black and White Rhino) and that the workshop would not attempt to establish priorities among them.

Once again the method described by Fatti [6] was used to obtain consensus in the workshop on the various pairwise comparisons required to establish priorities amongst the three main criteria, as well as amongst the various sub–criteria, in the hierarchy. The pairwise comparisons matrix for the three main criteria is given in Table 3, together with their estimated priorities. As before, the Delphi method yielded highly consistent results.

TABLE 3

Pairwise Comparisons Matrix and Estimated Priorities for the three Main Criteria used for Establishing Conservation Priorities for Elephant and Rhino Populations

	Biological Importance	Threat Status	Likelihood	Priorities
Biological Importance	1,0	1/4,5	1,1	0,154
Threat Status		1,0	5,3	0,709
Likelihood			1,0	0,137

Inconsistency Ratio: 0,04%

It is interesting to note the priority weightings which the participants allocated respectively to the three main critèria "Biological Importance", Threat Status" and "Likelihood of Funding achieving Conservation Goals", reflecting their chief area of concern.

Since there were far too many populations in each of the three species for pairwise comparisons to be performed amongst them, the 5–point scoring method described by Fatti [6] was used by the participants to assess the importance of each of the populations relative to each of the twelve sub–criteria in the hierarchy. The same set of priority scores as derived by Fatti [6] was used for the five categories, and for each sub–criterion each category was associated with a clearly defined status of the sub–criterion. For example, the categories of the sub–criterion "Trend" were assigned as follows:

Trend	Category	Priority
Declining Rapidly	A	0,531
Declining Slowly	B	0,254
Stable	C	0,120
Increasing Slowly	D	0,064
Increasing Rapidly	E	0,032

A spreadsheet program was used to perform the various calculations. The results are given in Table 4 for the case of the Black Rhino.

TABLE 4

	BLACK RHINO												
	BIOLOGICAL IMPORTANCE						THREAT STATUS		LIKELIHOOD OF ACHIEVING GOAL				
	POPULATION			AREA						FINANCIAL			
	GENETIC	SIZE	ECOTYPE	CAPACITY	CONSERV	RARITY	TREND	SECURITY	GOVCOMM	GOVINP	ECONPOT	INFRASTR	TOTAL
WEIGHT	0,025	0,030	0,070	0,019	0,010	0,078	0,302	0,330	0,087	0,010	0,024	0,016	
HL/UM	0,254	0,531	0,254	0,254	0,254	0,254	0,064	0,064	0,531	0,531	0,120	0,531	0,171
KNP	0,531	0,254	0,254	0,531	0,531	0,254	0,032	0,064	0,531	0,531	0,120	0,531	0,168
PILANS	0,254	0,064	0,254	0,120	0,254	0,254	0,032	0,032	0,531	0,531	0,120	0,531	0,134
ITALA	0,254	0,064	0,254	0,120	0,120	0,254	0,064	0,064	0,531	0,531	0,120	0,531	0,153
MKUZE	0,064	0,120	0,254	0,120	0,254	0,254	0,064	0,064	0,531	0,531	0,120	0,534	0,151
NDUMU	0,254	0,064	0,254	0,064	0,120	0,254	0,120	0,254	0,254	0,254	0,120	0,531	0,204
E.SHORES	0,254	0,064	0,254	0,120	0,254	0,254	0,064	0,064	0,254	0,531	0,120	0,531	0,130
WEENEN	0,120	0,032	0,254	0,032	0,032	0,254	0,032	0,032	0,254	0,531	0,120	0,531	0,101
ANDRIESVO	0,254	0,032	0,254	0,120	0,254	0,254	0,064	0,032	0,531	0,531	0,120	0,531	0,142
KASUNGU	0,120	0,064	0,531	0,120	0,120	0,531	0,254	0,120	0,254	0,120	0,531	0,254	0,243
N.BOTS	0,120	0,064	0,254	0,531	0,531	0,531	0,120	0,120	0,120	0,120	0,531	0,120	0,182
MWABVI	0,064	0,032	0,254	0,064	0,120	0,531	0,254	0,254	0,120	0,064	0,531	0,120	0,250
MOCAMB	0,531	0,531	0,254	0,531	0,531	0,254	0,531	0,531	0,531	0,032	0,531	0,032	0,478
MKHAYA	0,531	0,032	0,254	0,064	0,064	0,254	0,120	0,064	0,531	0,531	0,531	0,531	0,184
AUGRABIES	0,531	0,032	0,254	0,064	0,254	0,254	0,064	0,064	0,531	0,531	0,120	0,531	0,159
VAALBOS	0,531	0,032	0,254	0,120	0,120	0,254	0,032	0,032	0,531	0,531	0,120	0,531	0,138
ADDO	0,032	0,062	0,531	0,064	0,254	0,531	0,032	0,032	0,531	0,531	0,120	0,531	0,168
ETOSHA	0,531	0,254	0,254	0,254	0,254	0,254	0,254	0,254	0,254	0,531	0,254	0,531	0,268
DAMAR	0,531	0,254	0,531	0,254	0,531	0,254	0,254	0,531	0,254	0,120	0,531	0,254	0,380

From the final scores given in the last column of Table 4 it is clear that for Black Rhino the Moçambique population had the highest funding priority, followed by the Damaraland population. The populations at Kasungu, Mwabvi (Malawi) and Etosha were next with roughly equal scores while the Ndumu population followed a little way behind. Corresponding tables were produced for the White Rhino and Elephant Populations, allowing similar evaluations to be performed on the relative funding priorities for these populations. All three tables produced lively comment from the participants, but it was generally agreed that the priorities did provide realistic guidelines for allocating funds to ensure their maximum influence on the survival of these threatened species.

While the intention was that the participants should encourage their respective funding organisations to use the priorities to help them in their decisions about allocating funds towards conserving the different elephant and rhino populations, specific recommendations on how to do so were deliberately not given. As with the previous exercise, the possibilities range from selecting the individual, or shortlist of, most deserving populations on the basis of these priorities, or using them in a resource allocation algorithm.

An important spin–off from the workshop was that, by working through the exercise together, the participants, several of whom represented rival NGO's, were made more aware of the various criteria and their relative importances which should be taken into account when making funding decisions. This should give them a basis for negotiation when deciding about the allocation of the various funding projects amongst themselves.

4. CONCLUSIONS

Both problems described in this paper are typical of those which confront wildlife managers: decisions of great consequence, lack of structure, ill–defined and conflicting objectives with divergent opinions on their relative importances, and scarce resources. It is a utopian dream that Operations Research will be able to solve these problems for them. Nevertheless, OR decision modelling, using approaches such as the Analytic Hierarchy Process, can contribute significantly towards assisting wildlife managers to structure their problems, taking account of the different criteria which need to be considered, so as to enable them to identify and evaluate the various alternative options open to them.

The strength of the AHP in this context, which transcends the technical criticisms of some of its aspects, is its appeal to decision makers, who have little or no experience of OR, as a natural way of incorporating the different incommensurate, and often conflicting, criteria into the decision model and of establishing tradeoffs between them. Doubtless a number of other discrete alternative multiple criteria decision making approaches (possibly less controversial than the AHP) could have been used for these problems (see, for example, Zionts and Lofti [23]). What is important is that the approach be easily used and understood by wildlife managers, and the results readily checked against their intuitive feelings. To this end, a visual, interactive system in which the users can easily modify any judgement and observe the effect of this throughout the model is very helpful. In the Pilanesberg exercise there was some concern about the fact that the pairwise comparisons matrix given in Table 1, which established the priorities of the three overall objectives of the park, was completed at the start of the workshop, before the participants had become familiar with the process. This matrix was therefore reassessed at the end of the exercise, and the fact that this had only a very minor effect on the final priorities of the five park uses gave the participants an extra measure of confidence in them.

Another important requirement is that there be an effective method of achieving consensus on the judgements required from the participants at such a workshop. The Delphi technique, used in conjunction with the computer program which captured the participants' responses and projected their histogram on a screen, allowed them to assess immediately whether or not there was sufficient consensus in their responses. In the latter case a debate, followed by a re–evaluation of the particular comparison, usually achieved consensus.

Interestingly, the only "black box" aspect of the AHP, namely the extraction of priorities from the pairwise comparisons matrices, did not concern the participants at the workshops, although they were very interested in the inconsistency ratio which accompanied the priorities. Therefore the particular method of extracting the priorities, be it Saaty's principal eigenvector method or any other reasonable method (see, for example, Islei and Lockett [13] or Stewart [22]) is of less concern, as long as it produces a good measure of the consistency of the pairwise comparisons. In view of the reported shortcomings of Saaty's [15] measure based on the principal eigenvalue, it may be worthwhile considering employing another measure, such as that proposed by Golden and Wang [9].

While the actual models and the numbers which emanated from these two case studies are of importance in their own right, we (the author and the organisers of both workshops) believe that the real benefit from them was to demonstrate how OR modelling, and the AHP in particular, can assist wildlife managers with their decision problems. Given the importance and, in many cases, long term consequences of these decisions, it is hoped that the use of OR in their structuring and evaluation will become the norm, rather than the exception, in future.

ACKNOWLEGEMENTS

I would like to thank Dr Jeremy Anderson and Mr Anthony Ferrar, organisers of both workshops, for inviting me to participate in them, Mrs Kathleen Clarke for assisting at the Pilanesberg workshop and Miss Tanya Shenk for assisting at the Kruger National Park workshop. I would also like to thank two anonymous referees for their useful comments on earlier drafts of this paper.

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