THE ANALYTIC HIERARCHY PROCESS AND PARTICIPATORY DECISIONMAKING

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ABSTRACT

Managing natural resource lands requires social, as well as biophysical, considerations. Unfortunately, it is extremely difficult to accurately assess and quantify changing social preferences, and to aggregate conflicting opinions held by diverse social groups. The Analytic Hierarchy Process (AHP) provides a systematic, explicit, rigorous, and robust mechanism for eliciting and quantifying subjective judgments. It has been applied in many socio-economic planning situations. In the AHP, a hierarchy is used to organize decision-making criteria. Pairwise comparisons are made between criteria at each level of the hierarchy and between possible alternative courses of action (decisions). These comparisons lead to priority vectors which are propagated through the hierarchy to arrive at a final priority vector for the set of decisions alternatives. There are several ways in which the AHP can be used to permit natural resource clientele to engage in participatory decisionmaking. Several types of hierarchies, several hierarchy creation techniques, and two judgment elicitation approaches provide for flexible adaptation of the AHP method. These different scenarios are conceptually described, and brief examples are included from resources management planning and from highway bridge design. The flexibility of the AHP in a variety of decision-making scenarios makes it a useful tool for including disparate participants in a fair and objective manner.

INTRODUCTION

Special interest groups, and the public in general, scrutinize the management of public lands to a greater extent than in the past. These clientele demand a wide array of resource values be produced and protected. Traditionally, tangible products (e.g., timber, ores, water, etc.) and services (e.g., grazing, hunting and fishing, etc.) constituted multiple use management, which was mandated by law in the U.S. (National Forest Management Act, Public Law 94-588). More recently, however, these objectives have been replaced with a desire to include biological, social, and economic interests into a more holistic view of land stewardship (Unger and Salwasser 1991). In this new view, social and economic needs and desires are constrained by the biological limits of the land–where *biological* is interpreted in an ecological sense and focuses on long-term resource condition. This is particularly evident in the redirection of land management activities in the USDA Forest Service, where this approach has been labeled *ecosystem management* (FEMAT 1993).

Others prefer the terminology *landscape management* because the veneer of vegetation and other components is transient compared to the physical landscape.

The all-encompassing nature of this revised policy means that many more land-based values need to be integrated into the management of each parcel. Some values may be global and long-term in nature, while others may be specific to the culture, history, and economics of a particular region or locale. Nevertheless, desired social values are often not recognized and included until more stakeholders become involved in management discussions. Unfortunately, when this happens different stakeholder groups may have drastically divergent opinions as to what course of land management actions should be taken.

The crux of this dilemma is that each group may have different objectives for the land. Different objectives do not necessarily cause problems, though. Objectives represent only some set of desired values that each group considers important. But this nonconfrontational situation changes when it comes to implementation, i.e., management activities. Different objectives often give rise to conflicting management recommendations. These conflicts arise because each group tends to maximize their set of values without regard for other values. Also, from a biological perspective, maximizing one set of values, e.g., fiber production, may preclude simultaneously receiving other values, e.g., biological diversity, from a fixed unit of land.

So, two questions ensue regarding stakeholder participation in land management. First, how can we include many different stakeholders into the decision process? While democracy is very pleasing theoretically, it is notoriously slow and awkward in practice. So, including everyone, in the democratic sense, is not a possibility. A more ideal solution is to include everyone fairly and yet not get bogged down by the weight of a thousand different opinions. Second, how can we integrate all these different objectives and values? Once we have polled all the different stakeholders in some way, we still need to place their objectives into some sort of framework from which it is possible to make a set of "best" management recommendations.

In this paper we offer the Analytic Hierarchy Process (AHP) as a tool for working with many different groups and their differing opinions. First, an intuitive example illustrates the basic ideas inherent in the AHP. Second, several different application scenarios describe how the AHP might be used with such groups. Finally, two examples from the authors' previous work portray how effectively this approach can work.

THE ANALYTIC HIERARCHY PROCESS

Many decisionmaking situations involve preferential selection among some finite set of alternative items or events or courses of action. For a land manager, the list of alternatives might contain, possible timber harvest levels, inventory and monitoring activities, or watershed analyses. In the best circumstances, there would be some intuitive measurement scale that could be used for comparison and the best choice among the available alternatives then has a high score along that scale. By ranking alternatives on the basis of numerical scores, we create an implied priority for those alternatives. When the selection criterion is "least cost" for example, the measurement scale is obvious and choosing becomes easy. In most real-world situations, however, there is not a single, simple scale for measuring all competing alternatives. More often, there are at least several scales that must be used and often those scales are related to one another in fairly complex ways. In broad-scale, participatory decisionmaking, alternative courses of action arise from different stakeholders with different value systems, and yet this diversity must be accommodated and integrated.

The AHP (Saaty 1980) is designed to help with these types of decisions. It has been applied to a wide variety of problems (q.v. Zahedi 1986). Two important components of the AHP that facilitate the analysis of complex problems are: (1) the structuring of a problem into a hierarchy consisting of a goal and subordinate features of the problem and (2) pairwise comparisons between elements at each level. Subordinate features which are arranged into different levels of the hierarchy, may include such things as objectives, scenarios, events, actors, outcomes, and alternatives. The alternatives to be considered are placed at the lowest level in the hierarchy. Pairwise comparisons are made among all elements at a particular level with respect to each element in the level above it. Comparisons can be made according to preference, importance, or likelihood--whichever is most appropriate for the elements considered. Saaty (1980) developed the mathematics necessary to combine pairwise comparisons made at different levels in order to produce a final priority value for each of the alternatives at the bottom of the hierarchy.

An AHP Example

As a simple and easily understood example, consider the hierarchy in Figure 1, which is designed to enable one to select a satisfying college. The goal, *satisfying college*, appears at the top of the hierarchy. The criteria appear on the next level: *academic reputation*, *cost*, *campus beauty*, *local living climate*, and *social life*. The colleges to be considered are labeled A, B, and C at the lowest level. First, the criteria are compared pairwise with respect to their importance for producing a satisfying college experience. The scale of integers in the range 1-9 is used for comparison (Saaty 1990). One possible matrix resulting from these pairwise comparisons appears in Table 1. In this matrix, each value A_{ij} indicates how much more important, preferred, or likely row heading i is than column heading j. Corresponding matrix entries A_{ji} equal $1/A_{ij}$. Elements on the matrix diagonal are always unity. The normalized principal right eigenvector **c**' = [0.465, 0.326, 0.085, 0.097, 0.038] of this matrix represents the priority values of those criteria (Saaty 1980).

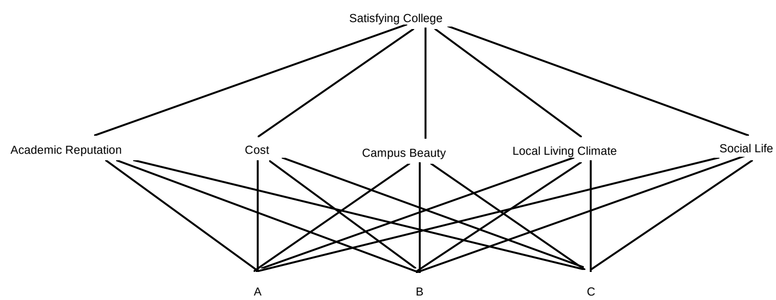


Figure 1. A simple analytic hierarchy for selecting a satisfying college from among three alternatives, A, B, and C, makes use of five criteria. Each of the alternative colleges is scored on each criteria. In general, however, a hierarchy need not be fully connected in this way.

Then alternative colleges are compared regarding the extent to which each has these criteria. One matrix, such as Table 2, would be produced for each criterion. Similar to the matrix above (Table 1), a priority vector $\mathbf{w_1}'$ = [0.637, 0.258, 0.105] can be calculated from Table 2. Priority vectors $\mathbf{w_2}$, ..., $\mathbf{w_5}$ can also be generated for the remaining criteria. The degree to which the colleges possess each criterion (stored in the $\mathbf{w}_i$) is weighted by the importance of that criterion c_i and summed across all criteria to obtain a final priority value w_i for that college. In matrix arithmetic, the final priority vector $\mathbf{w}' = [w_1, w_2, w_3]$ for the colleges is calculated as

$$\mathbf{w} = [\mathbf{w_1}\ \mathbf{w_2}\ \mathbf{w_3}\ \mathbf{w_4}\ \mathbf{w_5}]\ \mathbf{c} \quad (1)$$

A more detailed example of the AHP process appears in Schmoldt and others (1994) with some of the mathematical derivations. Because the final result of the AHP is a numerical priority value for each alternative, the decisionmaker may then select the highest scoring alternative as the "best." The decision process that has been made explicit in the hierarchy and in the comparisons determines this "best" alternative.

Table 1. The five criteria for selecting a college are compared in a pairwise fashion and assigned a relative importance score.

	Academic Reputation	Cost	Campus Beauty	Local Living Climate	Social Life
Academic Reputation	1	3	5	3	7
Cost	1/3	1	5	5	9
Campus Beauty	1/5	1/5	1	1	3
Local Living Climate	1/3	1/5	1	1	3
Social Life	1/7	1/9	1/3	1/3	1

Table 2. The three colleges are compared with respect to the criterion, academic reputation.

Academic Reputation	College A	College B	College C
College A	1	3	5
College B	1/3	1	3
College C	1/5	1/3	1

Inconsistent Judgments

Because the judgments in each matrix are subjective, there is no guarantee that the pairwise comparisons are consistent with one another. That is, three items, A, B, and C are consistent when, if A is preferred to B and B is preferred to C, then A is preferred to C. Because we are assigning numerical values to these preferences, slight inconsistencies in judgments become readily apparent. In fact, unless we are applying some explicit measurement scale, such as a meter stick, inconsistent judgments can be expected. Only large deviations from consistent judgments, however, need to be examined carefully.

Mathematically, an inconsistent judgment matrix translates into multiple right eigenvectors for the matrix. The difference between the maximum (principal) right eigenvalue and n, the rank of the matrix, provides a measure of inconsistency among the judgments. Inconsistencies are not undesirable or unwarranted in all cases. Some decision problems have inherent inconsistencies, e.g., when evaluating the best sports team. Because any team can beat any other team on any given outing, inconsistent judgments can easily result if pairwise performance between teams is used for comparison. The AHP provides a mechanism for estimating inconsistency and for evaluating its importance.

Extending Pairwise Comparisons

As the number of items being compared increases, the mathematical ability to detect inconsistency decreases. For this reason, and the fact that it is humanly difficult to compare more than 7±2 items simultaneously (Miller 1956), comparison matrices should be limited to seven items or less. However, the number of items that must be compared at any level in the AHP often exceeds seven. When this occurs, there are two possible courses of action. First, a hierarchy can sometimes be re-structured to insert additional layers that subdivide items on a level (the example in Fig. 4 does this). Suppose, for example, in our illustration above that we had ten criteria instead of five. We might combine *local living climate* and *social life* under a new item *social/cultural amenities*, that would replace those two items in our original layer. The alternatives would then be scored against each of the original criteria as before. The reorganized hierarchy would appear like in Figure 2.

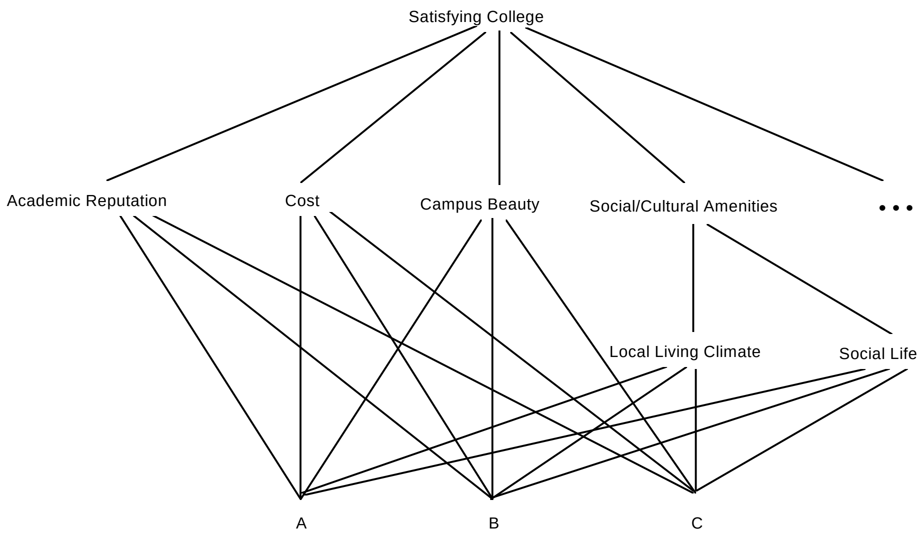


Figure 2. We can reorganize a hierarchy by adding additional layers to eliminate the comparison of more than seven items simultaneously.

Second, a variant of the pairwise comparison technique can be used when more than seven alternatives need to be compared at the bottom of the hierarchy. Under these circumstances, an arbitrary rating scale is developed for each element in the hierarchy against which the alternatives are compared. Then each alternative is scored along the scale for each rating element. For example, if there were ten colleges to be compared in the example above, we might create a rating scale for *academic reputation* that contained the values "bad," "fair," "good," and "excellent." Relative numerical scores would be created for each of these *academic reputation* values by comparing them in the usual pairwise fashion. Then each of the colleges would be assigned a score, "good", "bad", etc., from this scale. A similar rating scale would be constructed for each criterion. After all the rating scales are developed, a long list of alternatives can be scored quite quickly in a spreadsheet-like format.

APPLICATION OF THE AHP

The AHP has been implemented in software under the tradename Expert Choice (Expert Choice, Inc., Pittsburgh, PA [tradenames are used for informational purposes only; no endorsement by the U.S. Department of Agriculture or the U.S. National Biological Survey is implied]) We have found that this software greatly simplifies construction of hierarchies and calculation of priorities; it also provides some informative graphic displays of results. The interactive nature of Expert Choice makes it effective for eliciting judgments and receiving feedback on the results of those judgments.

In this section we explore some of the different ways in which the AHP can be applied in participatory decisionmaking through the construction and analysis of hierarchies.

During these derivations we assume that the following three conditions hold: (1) the number of interested parties (groups) is small enough to be pragmatically manageable, (2) it is possible to assemble representative members of each group as spokespersons, and (3) those representatives can be expected to contribute in an unimpassioned and rational manner. For the first condition, we can select the most vocal or influential or knowledgeable groups as the ones most necessary for inclusion. For the second, each group can be requested to submit one or more delegates, who are well-versed in the desires and aims of their group membership. The third condition may be difficult to guarantee, but we can supply coaching in the AHP approach to help engender analytic thinking, thereby mitigating problems introduced by overly zealous participants. As discussed below, we can also elicit individual responses separately and weight responses according to subject matter expertise.

Types of Hierarchies

The ability to combine and subdivide hierarchies (as we did in Fig. 2) provides considerable flexibility in how we engage decisionmaking participants. In this subsection we explore several possible hierarchy structuring approaches. These types of hierarchy structuring methods are not all mutually exclusive. For example disjoint hierarchies can be created for the different groups making up the stakeholders, but each of these hierarchies can have their levels and items in each level predetermined, i.e., static. As we present these methods there is one tacit assumption that we must adhere to. Because we need comparable final priority vectors for each group, we require that each hierarchy contains the same set of alternatives in its final comparison.

Composite Hierarchy. Imagine that we start with a hierarchy, such as in Figure 3, as a framework for timber harvest decisionmaking. This type of hierarchy gives our decision problem a global perspective because we have specifically included generic forces acting on the main goal and have included stakeholder preferences. Examples of clientele groups might be owners of inholdings, conservation groups, local economic planners, and local residents. A land manager might construct such a hierarchy and provide professional judgments about the comparative importance of the forces and the clientele groups. By weighting the input of clientele groups, the land manager may be able to mitigate the overly impassioned views of some participants (see the assumptions listed above). Each clientele group would then complete their respective portion of the hierarchy. Under this scenario, each group could specify their own objectives (dynamic hierarchy) or they could use a list of objectives supplied by the land manager (static hierarchy). The only requirement, as noted above, is that the list of alternatives used by each group is the same. Presumably, the land manager would have created the alternatives list based on prior consultations with various stakeholders. After each group has completed their portion of the hierarchy, the land manager creates a composite hierarchy consisting of the results from each group's sub-hierarchy and from the judgments made by the land manager for the upper two layers. The global result is a final priority vector for timber harvest activities.

Disjoint Hierarchies. In the previous method, separate sub-hierarchies are created by each clientele group. These sub-hierarchies are components of a larger, more inclusive hierarchy of decisionmaking. In some cases, a land manager may not wish to presuppose such an overall structure for the decision process. One way to avoid a global structure is to ask each clientele group to develop their own decisionmaking hierarchy, completely independent of the other groups. Each disjoint hierarchy can be either static or dynamic, just as in the case of the composite hierarchy. Once the individual hierarchies have been developed, the land manager still needs to integrate them in some way. This can be done in several ways: (1) weight the importance or contribution of each group, similar to what was done in the composite hierarchy case, or (2) interpret the final priority vectors of each group in a general qualitative way as a survey of public interest, or (3) apply statistical procedures to identify differences between groups (see the Rural Bridge example below).

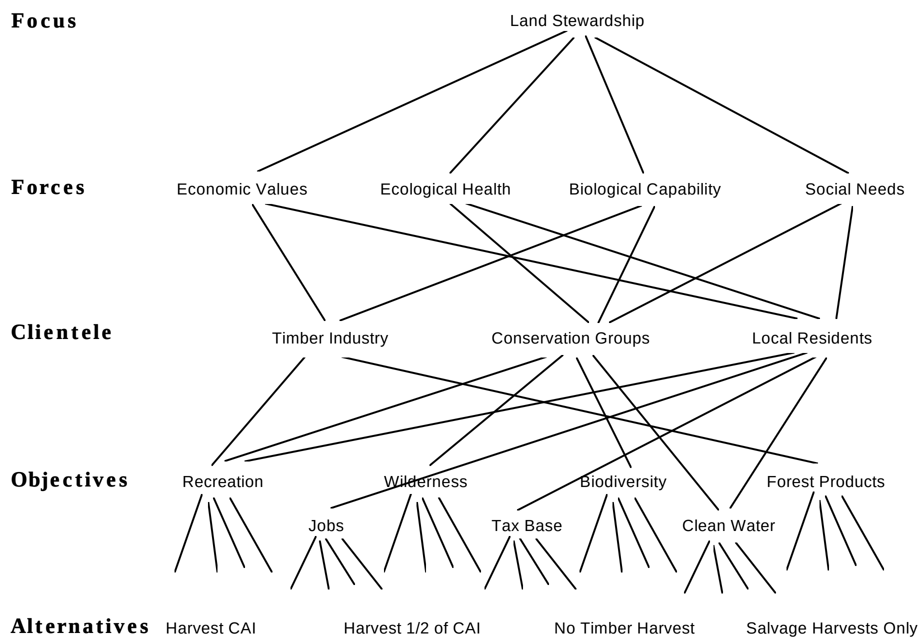


Figure 3. A global decision hierarchy can explicitly include clientele and the forces acting on the main goal, in addition to the objectives and alternatives used in the previous hierarchies. The objectives layer is fully connected to the alternatives layer in this figure (CAI refers to current annual increment of wood, usually on a per land area basis).

Plenary Hierarchy. Each of the previous two approaches has kept the deliberations of the different groups separate. An obvious alternative is to put groups together and have them create a single hierarchy in a plenary setting. While there may be many social obstacles to such a procedure, it also has some advantages. First, a single, final and complete hierarchy is created; no integration needs to be done. Second, the opportunity for different stakeholders to meet together and discuss various issues may encourage them to retreat slightly from their extreme positions. Third, if less extreme viewpoints are generated, these will result in more centralized final values, which should better reflect the views of a "reasonable and well-informed individual." Fourth, because everyone is together at the same time, there is usually no need to create and use a static hierarchy, therefore the final product need not be constrained by pre-established layers.

Static Hierarchy. It can be desirable to construct hierarchy layers and layer items a priori, such as in Figure 3, before convening the groups. Then, group members need only focus their efforts on making pairwise comparisons. Not only can final priority vectors be statistically compared, but the uniform nature of a single hierarchy also allows statistical comparisons to be made on the layer of objectives (or whatever other layers have been included). See the Timber Bridge Design example provided below. This is clearly not possible when each group may have different hierarchy layers and different layer items. Also, because there is no discussion of hierarchy structure, this method tends to consume much less time. The static hierarchy also facilitates the formalization of pairwise comparison steps by means of a survey instrument. Therefore a large number of participants can be included in the process very easily.

Dynamic Hierarchy. Because static hierarchies avoid any modification of hierarchy structure, they unnaturally constrain group participants to fit their decisionmaking structure into someone else's hierarchy. However, any given, predetermined hierarchy may not accurately reflect each group's internal decision procedures. On the other hand, when creating dynamic hierarchies, participants are allowed to add layers and layer items that they feel are necessary. Ultimately, this may ease the pairwise comparison task because when the hierarchical structure naturally mirrors their way of thinking about the problem, judgments come forth more easily–and possibly more accurately.

Creating a Hierarchy

The previous section presented several different types of hierarchy structures and their persistence (static vs. dynamic). At some point, however, someone or some group must actually identify layers and layer items. There are a number of commonly used group think techniques that can be useful here. Probably the most familiar, *brainstorming*, simply provides for face-to-face discussion between individuals with the intent of idea generation. The *nominal group technique* (Van de Ven and Delbecq 1971) has a similar group meeting scenario, but with slightly more structure. Each participant offers an idea in turn and group discussion follows each idea. When no more new ideas can be offered, the session ends. The *Crawford slip method* (Crawford and Demidovich 1981) is a variant on the nominal group method in which ideas are written on individual slips of paper; these are then discussed with each idea having anonymous authorship.

Another group technique that aims to maintain anonymity for participants' ideas and opinions and to avoid confrontation is the *Delphi technique* (Dalkey and Helmer 1963). Standard implementation of the Delphi employs questionnaires to which each member of a group anonymously responds. Questionnaires are repeatedly administered to members of the group for revision, intermixed with feedback of questionnaire summaries until some consensus has been reached. Group interaction is minimized to avoid voice dominance by position or persuasiveness, and to reduce the group pressure to conform (von Winterfeldt and Edwards 1986).

There may be additional group elicitation/discussion methods that can also be used. To be most effective, any technique that is used should permit: (1) unrestricted offering of ideas, (2) group discussion that addresses pros and cons, and (3) final acceptance or rejection of each offering, either by acceptance vote or by lack of dissent.

Expressing Judgments

No matter which type of hierarchy we use or what layers and layer items it contains, pairwise judgments must eventually be made. When compiling subjective judgments, whether from several people or several groups of people, there are two basic ways to aggregate multiple estimates. One option is to obtain consensus among the participants regarding each comparison. The second possibility is to mathematically combine individual judgments to arrive at a group average for each comparison. The following two paragraphs explore those two approaches.

Consensus Judgments. Pairwise comparison by consensus means that there must be some general agreement by all the participants for each comparison. This can become very difficult for members of groups that have diametrically opposed philosophies and starkly contrasting agendas. Consequently, consensus methods usually are best applied to judgment assignment tasks within individual groups. As with the elicitation of layers and layer items, group think methods are appropriate (see Creating a Hierarchy). However, as participant differences become greater, the more anonymous and less confrontational methods work best.

Averaging Judgments. Individual judgments require much less anguish (in discussion) and less time, and they can readily be combined mathematically. Because pairwise comparisons in the AHP are based on a ratio scale, judgment averages should be calculated using a geometric mean (Saaty 1980). The average A for a set of judgments X_i is

$$A = \sqrt[n]{\prod_{i=1}^{n} X_i} \qquad (2)$$

If the land manager, or some other decisionmaking authority, wishes to weight the contribution of n clientele groups, as in Figure 3, the weighted geometric average A_w would incorporate an integer weight value j_i for each clientele group.

$$A_w = \sqrt[k]{\prod_{i=1}^{n} X_i^{j_i}}$$

$$\text{where} k = \sum_i j_i \qquad (3)$$

Judgment averaging is only applicable, of course, in the case of a single hierarchy or in the case of static hierarchies, where each participant compares the same items with respect to a corresponding item.

EXAMPLES

The flexibility inherent in these different hierarchy construction methods and judgment elicitation techniques makes the AHP useful for a variety of different problems. This section presents two very different applications of these methods, one in resource management planning and one for rural bridge material selection. In the first example, the AHP is used to model a normative decision process, i.e., where the final result indicates what decision should be made. The second example, in contrast, uses the AHP to represent a behavioral decision model, i.e., how some group or groups of individuals make a particular decision. The ability to deal with normative, as well as, behavioral decision problems further underscores the broad functionality of the AHP.

Resources Management Planning

The AHP is relevant to nearly any resource management application that requires multiple opinions, multiple participants, or a complex-decisionmaking process. Considering the complexity of most resource management issues and compliance regulations, AHP could extend to a wide array of managerial and planning tasks. For example, management and planning for a large watershed may include issues related to water quality and quantity, forest management, wildlife management, and recreation. Input is required from subject matter experts in each of these disciplines in order to establish priorities and make informed decisions regarding spatial and temporal distribution of resources. Management and planning for wetlands can also be quite complex, and should include issues related to hydrology, aquatic ecology, forestry, wildlife, fisheries, and recreation. Because both watersheds and wetlands generally involve the flow of materials between public and private lands, additional input is needed on social, legal, and political aspects of resource condition and value.

Application Overview. Although some resource managers initially find the AHP intimidating, we have found that they feel very comfortable with quantitative decision-making tools after some hands-on experience. For example, we recently worked with the resource management staff of Olympic National Park in Washington state, USA, in order to determine the usefulness of the AHP in actual practice (Peterson and others 1994). We selected this park because it is large (380,000 ha) and has a diverse array of natural resources. It also has a diversity of management issues, including several with prominent legal and political ramifications. The complexity of resources management at Olympic NP is evidenced by the fact that the resource management plan (RMP) is over 700 pages. This is not atypical for large national parks, because the RMP is generally a long-term, comprehensive document for planning and project development.

The planning process is not highly structured at the present time. As one member of the staff at Olympic NP put it, they use the “BOGSAT (Bunch of Guys/Gals Sitting Around a Table) method of planning”. In other words, the management staff compiles a wide range of topics, discusses them, prioritizes them, and develops the RMP with minimal quantitative evaluation and without formal decision-making tools. The result is a large and rather cumbersome document.

The RMP provides a formal goal-setting process for national parks. A comprehensive summary of an ideal management strategy is a valuable source of information, but it is also a source of frustration for park personnel. There is nearly always a huge gap between the management programs described in the RMP and the actual programs that are constrained by budget and personnel limitations. Park managers see many critical needs for information; but they also realize that many of those information gaps will never be filled. As a result, they are continually faced with the prospect of making decisions in the absence of adequate data. They are also faced with deciding whether to develop an extensive program (many projects at a low level of detail) or an intensive program (a few projects at a high level of detail). Finally, park managers are often faced with political and operational constraints that may override decisions based on scientific information and resources management expertise.

Budget allocation among different resource areas within a national park is a difficult process because of the wide range of resources, personnel, and issues involved in implementation of RMP projects. It is only normal that a fishery biologist would support projects related to collecting data on fish populations, or that a wildlife biologist would advocate greater study of certain wildlife species. Despite potential advocacy associated with specific projects in the RMP, the park staff must establish priorities for which projects can actually be conducted. Olympic NP currently has no formal process for prioritizing projects and allocating budget and personnel among projects. Park staff indicated that this is a frustrating situation, particularly because of unpredictable annual budgets. The two-step process of prioritization and allocation (Peterson and others 1994, Schmoldt and others 1994) makes decisionmaking more explicit and allows plans to be reexamined and more easily modified.

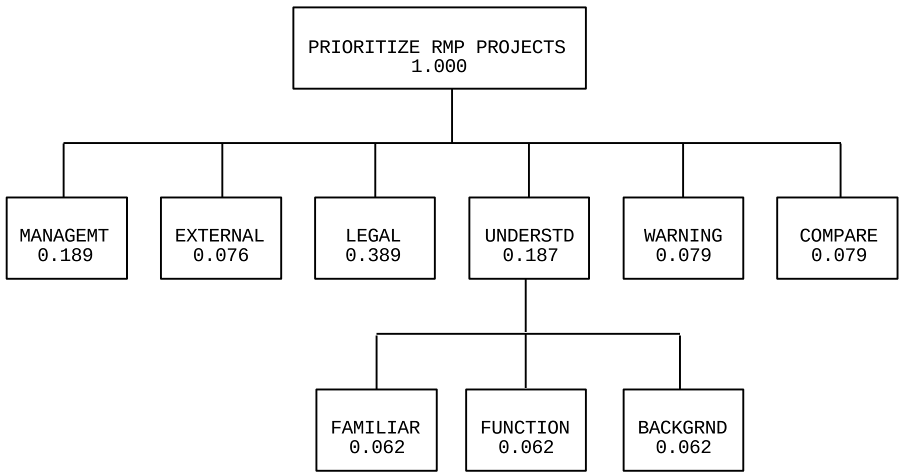
Interviewing with the AHP. We worked with five members of the Olympic NP staff (Resource Assistant, Resources Management Specialist, Wildlife Biologist, Fishery Biologist, GIS Specialist) to determine how the AHP could be used to prioritize RMP projects. Discussions were conducted over a two-day period while all members of the group were present. Eight projects were selected for the priority-setting exercise, one from each of the resource disciplines in the natural resources section of the current RMP.

Pairwise comparisons and project ratings within the AHP were developed interactively by projecting each view from a computer monitor directly onto an overhead screen so everyone could discuss the same topic simultaneously. All subjective judgments were reached by consensus within the resources management team. After the Olympic NP team became more comfortable with the format of the AHP procedure, decisions could generally be reached with a minimum of discussion. The authors were frequently consulted in order to clarify wording or meaning of various sections of the exercise. Although there was often disagreement about subjective assessments, there were few cases in which staff members' judgments were more than one score different from each other.

In addition to rating individual projects with respect to each objective and sub-objective, the Olympic NP team also developed relative weights for the objectives themselves. Specific objectives and their organization had been developed previously by the authors (Schmoldt and others 1994). We expected the Olympic NP team would create their own hierarchy for this exercise, but instead, they opted to use the existing structure for park objectives (Fig. 4). In terms of our conceptual development, above, this study used a static hierarchy in a plenary setting, with participants reaching consensus as a group. Two other priority vectors for the objectives were used as part of the final analysis, these included: (1) all objectives have equal weight, (2) *management decisionmaking* has exclusive priority.

AHP Results. The final project ratings and their associated ranks indicate that the five highest priority projects all had relatively high priority scores, while the three lowest priority projects had considerably lower scores (Table 3). A different scenario in which all objectives in the model were ranked equally produced only minor changes in the order of project priorities; the highest and lowest ranked projects maintain their positions, while the middle four projects are reordered. However, a scenario in which "management decision-making" was the only important objective caused a considerable shift in priorities. Results for a scenario in which rankings were based on 1990 RMP expenditures for projects differed markedly from each of the previous sets of rankings. This indicates that allocations using the "BOGSAT process" followed a non-explicit set of objectives which diverge from those of the other explicit resource management planning scenarios.

RESOURCE MANAGEMENT OBJECTIVES IN MODEL



MANAGEMT --- SUPPORT MANAGEMENT DECISION-MAKING
EXTERNAL --- INFLUENCE OUTSIDE DECISION-MAKERS
LEGAL --- SATISFY LEGAL MANDATES
UNDERSTD --- BETTER UNDERSTAND RESOURCES
FAMILIAR --- MAINTAIN FAMILIARITY WITH RESOURCES
FUNCTION --- UNDERSTAND ECOSYSTEM FUNCTION
BACKGRND --- PROVIDE BACKGROUND INFORMATION
WARNING --- EARLY WARNING OF GLOBAL OR REGIONAL PROBLEMS
COMPARE --- PROVIDE COMPARISON WITH UNEXPLOITED AREAS

Figure 4. The hierarchy for RMP includes the primary goal and the objectives. Each of the 8 alternative projects were compared with respect to these 8 objectives.

In the case study conducted for Olympic NP, we found that the resource managers were receptive to alternative approaches for the evaluation of resource management planning. The complexity of multiple objective planning and project prioritization was simplified with the use of the AHP. Furthermore, resource management staff felt that they could present the RMP to other park staff and the general public with greater confidence if it were grounded in quantifiable decisions. Although this case study assessed only a few projects and objectives, there was considerable support for integrating the AHP approach into other aspects of resource management planning.

Timber Bridge Design Criteria

Overview of Bridge Design. Highway officials and engineers across the United States have been asked to re-evaluate their position on the use of timber as a bridge material. Extensive promotion and training began in 1989 by the Timber Bridge Initiative Program (TBIP 1990) to inform and educate bridge engineers and highway officials concerning the benefits of the modern timber bridge. It is believed that with an increase in the use of timber, local economies can be stimulated and the rural infrastructure rebuilt.

The choice of a material is the most important decision bridge designers make, and it has long-term consequences for the owner of the structure (Johnson 1990). Bridge material selection is a complex decision, with many individuals involved, and many factors of bridge design, use, and maintenance to be considered. It is not uncommon to have state Department of Transportation (DOT) officials, private consultants, and local officials work together on a bridge replacement decision. Each of these groups may have their own preferences concerning bridge materials. Often a consensus is necessary to determine the best material to use at a given location.

Table 3. Priority ratings and rankings for each project under different management objective priorities are listed. Staff ratings for each project, along with the relative importance of management objectives under each scenario, produced the final priority values in this table.

Project	Objective importance assigned by park staff		All objectives ranked equally		"Management decisionmaking" has highest priority		Actual funding level in the 1990 RMP implicitly determines rankings	
	Priority	**Ranking**	**Priority**	**Ranking**	**Priority**	**Ranking**	**Priority**	**Ranking**
Air quality	.137	5	.130	6	.099	7	--	3
Avalanche monitoring	.069	8	.057	8	.111	6	--	2
Water quality	.140	4	.146	3	.122	5	--	5
Goat impacts	.141	3	.135	5	.179	1	--	1
Sensitive wildlife	.143	2	.149	2	.134	4	--	5
Anadromous fish	.128	6	.143	4	.145	3	--	4
Elwha watershed	.148	1	.163	1	.168	2	--	5
IPM program	.095	7	.077	7	.042	8	--	5

Many factors are known to effect the choice of a bridge material. *Site specific factors* include: roadway alignment, length of clear span, clearance above waterway, hydraulic capacity requirements, and required loading capabilities. Yet, there are numerous *non-structural characteristics* identified in this study that influence bridge material selection. The most important ones include: initial cost, maintenance requirements, expected life of material, past performance, resistance to natural deterioration, and lifecycle cost.

Interviewing with the AHP. An AHP model was developed with: 6 decision criteria, 3 decision groups, and 4 material alternatives (Fig. 5). Semi-structured interviews were conducted with 73 design engineers and highway officials in four selected states: Mississippi, Virginia, Washington, and Wisconsin. State department of transportation engineers involved in preliminary design or local bridge maintenance/replacement decisions were interviewed as state DOT engineers. Private consulting engineers who were involved with local bridge design and county highway officials also participated in this study. Interviews with county officials and private consultants were limited to one engineer per location.

Composite AHP models were developed for each group of decision-makers (DOT engineers, local officials, and private consultants) in the four separate states (Smith and others 1994). A questionnaire was designed for participants to use for completion of the AHP model. This questionnaire consisted of paired comparisons among the six selected decision criteria and among the different types of bridge material with respect to each decision criteria. A rating scale from 1 to 9, as recommended by Saaty (1980), was used for the paired comparisons.

Each decision-maker made 51 paired comparisons to complete their individual AHP model. A laptop computer running Expert Choice was used to record responses as each official filled in the questionnaire. This allowed immediate feedback to the decision-maker on their preferences and their overall choice of a bridge material. Individual results were then combined as geometric means to produce with-in group decisions representing the separate decisionmaking groups in each state.

AHP Results. By using a static hierarchy, we were able to make statistical comparisons both, between the alternative bridge materials available and between the criteria decisionmakers used in their thinking (Fig. 6). When all four states were considered in aggregate, differences existed in the preference for steel and timber among the three major decisionmaking groups. Within individual states, material preference differences also existed between the different groups. For example, in the states of Virginia and Wisconsin differences existed between decision-makers' preferences for timber, and also, both prestressed concrete and reinforced concrete were deemed to have different preferences across decision groups in Mississippi.

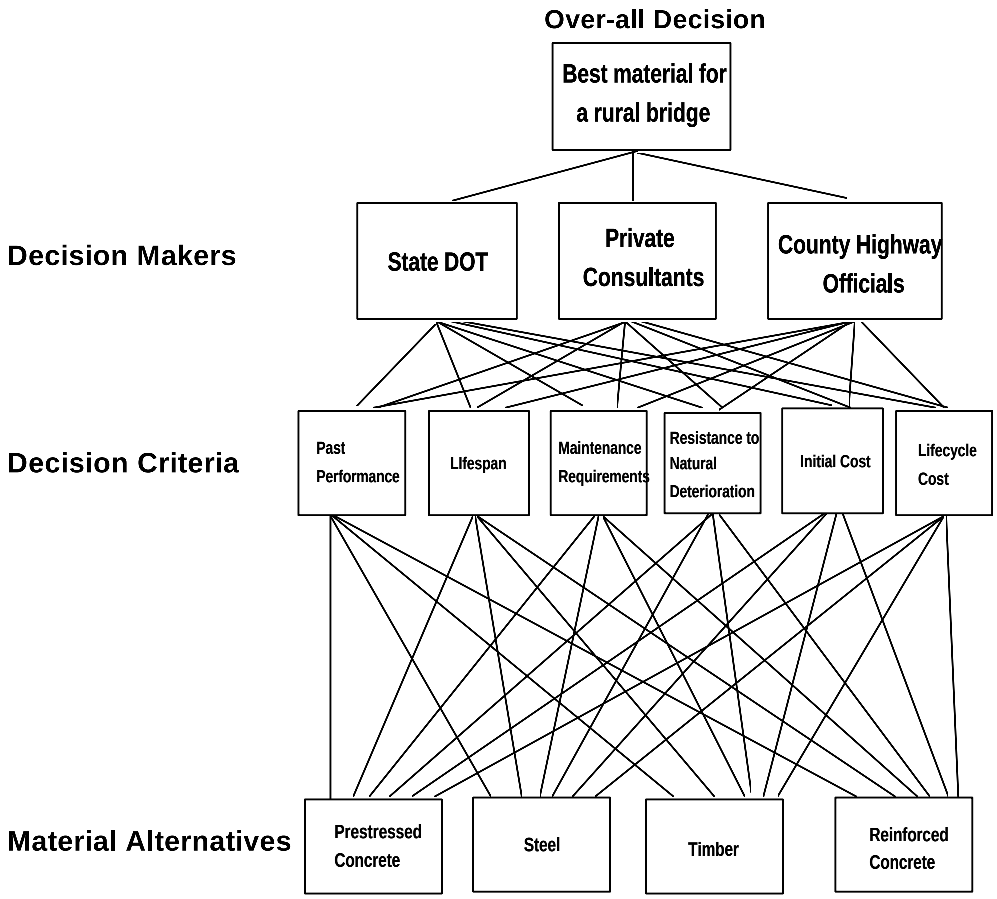


Figure 5. Material selection for rural bridges incorporates three decisionmakers, six decision criteria, and four material alternatives.

Decision-makers are in good agreement about *criteria* that are important in the design decision. Across the United States, these individuals rated the most important criteria similarly by region and decision group. *Maintenance requirements, initial cost, and past performance* were the most influential criteria in choosing a bridge material. However, these criteria, when applied to the AHP decision models, influenced the choice of bridge material differently. These results indicate that even though decision criteria are viewed similarly, the extent to which various bridge materials are perceived as meeting those criteria vary between states and between decision-making group.

CONCLUSIONS AND DISCUSSION

The structured approach offered by AHP allows different individuals and institutions to participate equally in a process that is quantitative and non-biased, rather than subjective and value-laden. If individuals can work around a table to quantify their input to decision-making, then an analytical process can provide a critical link in developing trust and true group participation. The AHP allows diverse viewpoints to be considered and integrated, without the requirement of consensus. The important thing is that all participants have input to, and ownership of, the final evaluation.

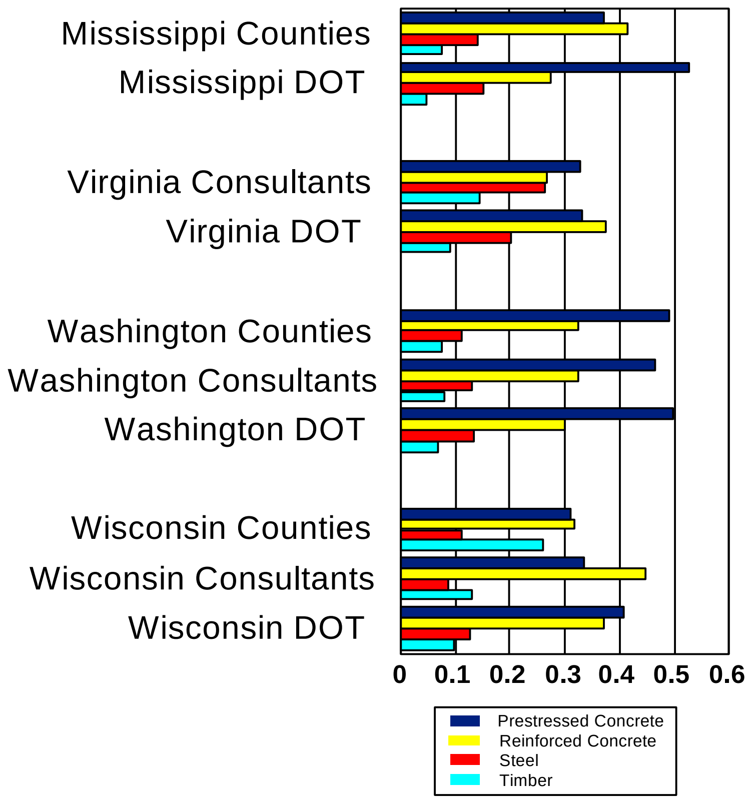


Figure 6. Final preferences for bridge material are presented for each state and decision-making groups within each state.

A tangible example of how group decision-making could be more effectively implemented is Biosphere Reserve management. Biosphere Reserves (e.g., di Castri and Robertson 1982) typically involve large land areas and multiple institutions, ownerships, and management objectives. Each reserve normally has a highly protected central zone, with greater levels of human use and resource exploitation as one moves away from the center. The spatial arrangement is commonly found on public and adjacent private lands throughout North America. Management of Biosphere Reserves is intended to involve all affected parties, including local communities. In fact, Biosphere Reserves are administered this way in much of the world, with the notable exception of North America. There are many such reserves in North America, but management and decision-making rarely involve inter-institutional cooperation and the participation of local communities.

Public planning and the management of public lands are being subjected to increasing levels of scrutiny. Appeals and litigation often delay the implementation of projects that were conceived with great effort and expense. The complexity of management issues, and the vociferous desires of multiple stakeholders, make it imperative that land management agencies have rational, consistent, and defensible management systems. The AHP may offer an opportunity to integrate both institutional diversity and social diversity in an internationally recognized framework, if institutional and political constraints are relaxed to allow true cooperation and understanding. In this way, the public can constructively contribute to, cooperate with, and direct management efforts, rather than work in opposition to plans that may not adequately address their interests.

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