USING THE ANALYTIC HIERARCHY PROCESS FOR PROJECT SELECTION IN MUNICIPAL RIVER CORRIDOR PLANNING

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Municipal water resource and land planning is a challenging process that involves the integration of scientific, political, and socioeconomic considerations to generate recommendations for future land use within the community. In the arid Southwest, this process is further complicated by the strong emotional undercurrents surrounding water rights and water-use issues. With scarce resources at its disposal, a municipality must take care in selecting how to pursue the objectives outlined in its general plan. When deciding among alternative projects, the need to balance public preferences, administrative and technical feasibilities, and efficiency concerns can overwhelm even the largest and most capable agencies or municipalities. For this reason, decision models have been suggested as an effective means to structure and guide the process of selecting projects for implementation.

The purpose of this paper is to discuss the feasibility of using a modified analytic hierarchy process approach for selecting municipal land-use projects to implement in a river corridor planning context. The Santa Cruz River corridor project, currently underway in Marana, Arizona, illustrates the advantages and drawbacks of this approach.

CASE STUDY

The town of Marana is located in southeastern Arizona, a few miles northwest of Tucson. Marana has a population of approximately 16,000 and was the fastest growing municipality in Arizona during the 1990s (Arizona Department of Economic Security 2002). Planning for and managing this growth is a critical task for the town.

Marana began a river corridor planning process in 1999 that is aimed at developing land-use plans which, in some manner, tie into the Santa Cruz River corridor. The Santa Cruz River is seen as being the central feature of the town and an important component in the both the social and economic well-being of the community. A fundamental goal of the corridor plan is to make the river a connecting feature rather than a barrier (Santa Cruz River Corridor Plan 2001).

Urban river corridor planning involves a special challenge due to the connection of land-use patterns and river characteristics. Significant urban development along the river channel and water quality considerations restrict the options that are available for land use, while hydrologic factors, such as flooding, add a degree of unpredictability. Because of these severe constraints, land-use alternatives are often quite expensive and their development merits careful and structured planning.

During the past 2 years the town has convened a Technical Advisory Group and a Community Task Force to develop a set of recommendations for land use. This early phase consisted of the gathering and organization of information relevant to the planning process. The next step will involve the identification of specific land-use opportunities and the development of detailed project plans. Due to limited resources, these projects cannot all be implemented simultaneously. As a result, a means of ordering the projects, on the basis of a set of decision criteria, is necessary. Looking ahead, the planning leader wishes to have a prioritization scheme in place before the projects are developed.

RATIONALE FOR USING A DECISION MODEL

The main purpose of implementing a decision model for prioritization of land-use projects, ultimately, would be to make better and more effective decisions. This is in keeping with one of the stated goals of the Santa Cruz plan to "Facilitate efficient use of municipal funds and resources" (Santa Cruz River Corridor Plan 2001, pg. 3). To this end, the model must provide a systematic and comprehensive framework for the comparison of alternative projects.

A decision model is also desired for the purpose of creating a formal and uncomplicated record of the decision process. A structured decision process

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not only necessitates a more careful evaluation of alternatives and a thorough discussion of assumptions, but also results in the documentation of the decision makers' logic and rationales. The result would be a better-informed decision process. Members of the planning staff believe that it is important not only to improve the quality of the planning decisions, but also to demonstrate to the public that the decision process was well informed, thorough, and thoughtful (M. H. Meyers, primary consultant for the Santa Cruz River Corridor Plan, personal communication 2002).

Finally, the project leader thinks it is important that the Santa Cruz planning process be consistent with other large-scale local planning decisions that currently involve various decision tools (F. Moghimi, project director for the Santa Cruz River Corridor Plan, personal communication 2002). Of particular note are the regional transportation improvement planning process and Marana's capital improvements planning process.

MODEL CHARACTERISTICS

The type of decision aid chosen for this project would also have to satisfy several needs identified by the planning leader. The model must be simple enough that planning staff and elected officials with no formal decision analysis training could understand and comfortably utilize the technique. In addition, the model has to be capable of combining quantitative technical and economic considerations with subjective public preferences (F. Moghimi, personal communication 2002; M. H. Meyers, personal communication 2002). A related concern is that the model should not be data intensive. The best model would utilize only data on hand or easily obtained and would not require extensive survey, data collection, or data analysis.

The model must also be capable of considering multiple perspectives. This planning process will involve the viewpoints of many elected officials and department heads. The planners also place a great deal of importance on incorporating public opinion into the decision process. Effective public involvement is not just about actual elicitation of preferences in a quantitative format; it also requires that the participants feel comfortable with the involvement process. Perception is key. If stakeholders do not feel that their input is making a real contribution to the decision-making process, they will have little faith in the planning outcomes. In the case of both the public and elected officials, users will only be comfortable with a model that leaves them in control of the decision process (Moghimi, personal communication 2002). From the perspective of the public, the model needs to be easy to use and must produce clear and understandable results. The town council and department heads want a process that will provide planning guidelines, not specific answers.

DESCRIPTION OF AHP PROCEDURE

The model selected for this river corridor planning process is the analytic hierarchy process (AHP). There are three basic components of the AHP procedure: decomposition, prioritization, and synthesis (Saaty 1990).

In the first step, the problem is decomposed into a hierarchy of criteria, subcriteria, and alternatives. The overall goal of the decision process—to prioritize land-use projects—is divided into a set of less generalized objectives that specify how the overall goal will be achieved. Each of the second-level objectives is further decomposed into increasingly specific criteria, until a set of concrete measures is reached. Finally, the alternatives are tied to all of the hierarchy branches, as each will be evaluated in terms of its performance on every factor in the lowest level of the hierarchy. An example hierarchy is presented in Figure 1.

Next, the relative weights of the criteria and subcriteria and the priority scores of the alternatives are generated using a series of pairwise comparisons. In this step, each element at a particular level of the hierarchy is compared to every other element within that level. These comparisons are made using Saaty's 1–9 absolute scale, where 1 denotes equal preference between the two elements and 9 indicates that the first element is "extremely preferred" to the second element. The intermediate numbers indicate varying levels of preference that are proportional to the value.

The pairwise comparisons are completed for each level of the hierarchy, including among the alternatives. These comparisons are used to generate weights for all criteria and subcriteria. The weights indicate the relative contribution of each factor toward achieving its parent objective. The alternatives are also compared against each other, on the basis of how well they satisfy each of the individual criteria. In this case, the pairwise information is used to construct "local priorities" that measure relative performance of an alternative on a single decision factor.

The final part of the AHP process is the aggregation of criteria weights and the local priorities

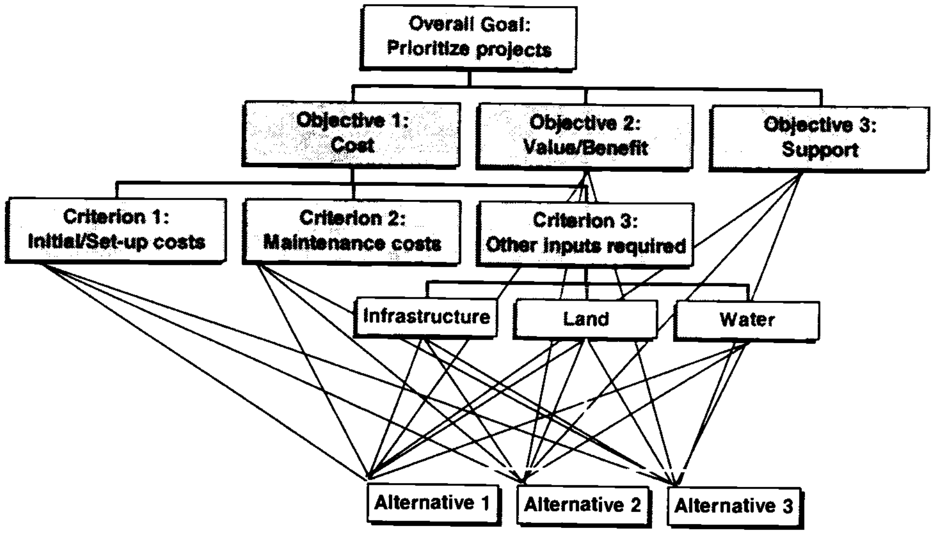

Figure 1: Sample AHP hierarchy.

for the alternatives. The ranking for each alternative is a function of how well that alternative performed on each criterion and the weights of those criteria. The formula for these scores can be expressed as

$$\text{Score}_i = ?\ LP_{ij}\ CW_j$$

where LP = local priority; the performance of alternative i on criterion j, and CW = weight of criterion j.

One additional component of the AHP analysis is the calculation of a "consistency index" (Saaty 1990). This index measures the extent to which the pairwise comparisons meet the transitivity assumption. This logical consideration states that if A is preferred to B, and B is preferred to C, then A must be preferred to C. The consistency measure can be very important for identifying when decision makers do not have a clear understanding of the chosen criteria or the alternatives and their relative performance. This lack of knowledge is one of the largest contributors to excessive inconsistency in the AHP analysis.

APPLICATIONS OF AHP IN THE PUBLIC SECTOR

Although many public sector applications have been explored, few real-world AHP case studies exist. In fact, Weistroffer et al. (1999) have noted that there have been few cases of any decision models being applied successfully in real-world situations. Rochat (1981) has proposed, however, that decision models could be appropriate aids in areas such as administration organization, common property management, roads and urban planning, waste management, traffic control, fire fighting, public utilities distribution, financial policy, public building construction, and school management.

One real-world application of AHP involved a municipal tax planning problem (Weistroffer et al. 1999). In this study, AHP provided a systematic approach to choosing a revenue base for the city. The city council, in this case, generated the criteria weights, while tax experts produced the local priorities for each alternative. The authors concluded that AHP was a suitable and beneficial tool for capturing subjective preferences toward various policy options, allowing for input from multiple decision makers, and providing a framework for pursuing consensus among the various participants (Weistroffer et al. 1999). Finally, the council members and experts both grew increasingly confident in and comfortable with the model over time.

Based on this and other studies, there is little doubt that AHP can provide additional insight into the trade-offs that underlie decision-maker preferences and improve the quality of the decision-making process (Holguin-Veras 1995; Mau-Crimmins and de Steiguer, in review). This simple and intuitive model supports flexibility and participant learning in decision processes (Holguin-Veras 1995; Kurtilla et al. 2000; Peniwati 1996).

PROBLEMS ASSOCIATED WITH THE USE OF AHP

The use of AHP in a municipal planning context, however, is not without problems. This methodology can require considerable time and effort on the part of decision makers. A problem involving a one-level hierarchy with 10 criteria and 6 alternatives requires decision makers to complete a total of 195 pairwise comparisons. If the problem size is increased to a two-level hierarchy with 4 criteria in the first level, 12 criteria in the second level, and 10 alternatives, the number of pairwise comparisons jumps to 612. Considering that any of these comparisons can involve substantial thought and discussion, this can make the entire process overly time consuming.

AHP was developed to support decision making by single individuals. Public decisions, however, typically involve multiple elected or appointed officials, agency heads, and/or stakeholders. Another important issue concerns how individual pairwise comparisons, weights and priorities, or final rankings should be aggregated. The most common approach is to average either the pairwise values or the weights and priorities from each of a group of decision makers (Mau-Crimmins and de Steiguer, in review; Schmoldt et al. 2001). Another approach is to solicit individual preferences and weight each according to the individual's importance, experience, power, or other relevant personal characteristic (Schmoldt et al. 2001). A final approach, one that seems more compatible with a public sector decision process, is to require consensus among the decision makers on their pairwise comparison preferences. The major drawback to a consensus process is that it is often achievable only when participants have shared goals and values (Li et al. 1999). This is rarely the case in a political decision process.

A final concern is the amount of prior knowledge that AHP requires of the decision makers. As Holguin-Veras (1995) has pointed out, not only must decision makers be familiar with operational considerations associated with the use of the model, but they also need to have a clear understanding of the criteria and a basis for evaluating alternative performance on the basis of these factors. Weistroffer et al. (1999) got around this problem by having the tax experts determine how well each policy alternative performs on the basis of the criteria and having the council simply determine the weights that would be applied to each criterion. Unfortunately, land-planning problems tend to involve larger scales, longer time frames, and more complex and diverse decision considerations. In these cases, it is unlikely that a single group of individuals has the necessary knowledge to adequately evaluate all aspects of the performance of each alternative. The remainder of this paper concerns ways in which these problems can be addressed in the context of a large-scale land-use planning effort.

MULTIPLE PLAYER MODEL

The AHP model proposed here adapts the participatory approach proposed by Schmoldt et al. (2001). These authors suggested that each group of multiple decision makers could either (1) create their own hierarchy and project rankings, (2) work together and generate a single hierarchy that all groups agree upon, or (3) create their own subhierarchy, which is then included in the overall model. There are several drawbacks to these approaches, however.

Public sector planning, as Schmoldt et al. (2001) noted, should be a participatory process. A key to creating compromise solutions among a variety of interests is to increase each group's understanding of the other participants. The first approach that Schmoldt et al. proposed will do little more than reaffirm the fact that different groups prefer different alternatives. This approach provides no mechanism for integrating or otherwise reconciling differing viewpoints.

The second tactic is equally problematic. Even if a group of diverse stakeholders could agree upon a single set of criteria to evaluate projects, it is unlikely that they will concur on the criteria weights or the local priorities assigned to the alternatives. Again, there is no explicit process for generating a single set of project rankings from the multiple stakeholder viewpoints. In addition, this approach requires that weights and priorities be determined by the entire group of decision makers, many of whom have little or no knowledge of some aspects of the problem.

The final approach suggested by Schmoldt et al. (2001, pg. 292) was also criticized by them for "allowing decision makers to constrain stakeholder input." In reality, however, local planning processes must accommodate political concerns that are so unstable and indistinct that they cannot be formally included in the decision analysis. In other words, the model is going to produce only guidelines for the planning process, not actual solutions (Meyer, personal communication 2002; Moghimi, personal communication 2002). The implication of this is that the structure of the model is less important for ensuring adequate public involvement than the way in which the model output is used. There is an additional problem with this approach, however. Like the first model, allowing groups to develop their own individual hierarchy does not facilitate the exchange of information and ideas that can lead to a clearer understanding of the full planning decision process. It is important that a single model be used by all stakeholders so that a unified vision of the problem is developed among the participants. Another significant problem with this approach is that it promotes the use of an excessive number of decision criteria. Past studies have found that the incorporation of redundant or irrelevant criteria can lead to poor analysis results (L. A. Bojorquez, School of Renewable Natural Resources, University of Arizona, personal communication 2002). What is needed is a succinct and minimal representation of the decision situation.

The model proposed here, the multi-player approach, modifies the third approach suggested by Schmoldt et al. (2001) to allow for an integrated problem representation, through the use of a single decision hierarchy. This multi-player model is defined by the community as a whole, but is restricted to the minimal set of criteria necessary to evaluate the alternatives. A visual comparison of the third model presented by Schmoldt et al. (2001) and the model presented in this paper is provided in Figure 2.

The multi-player approach also avoids the problems of the single-hierarchy methods that Schmoldt et al. (2001) proposed. In particular, stakeholders do not provide preference information for all of the alternative comparisons. Each participant evaluates alternatives only on the

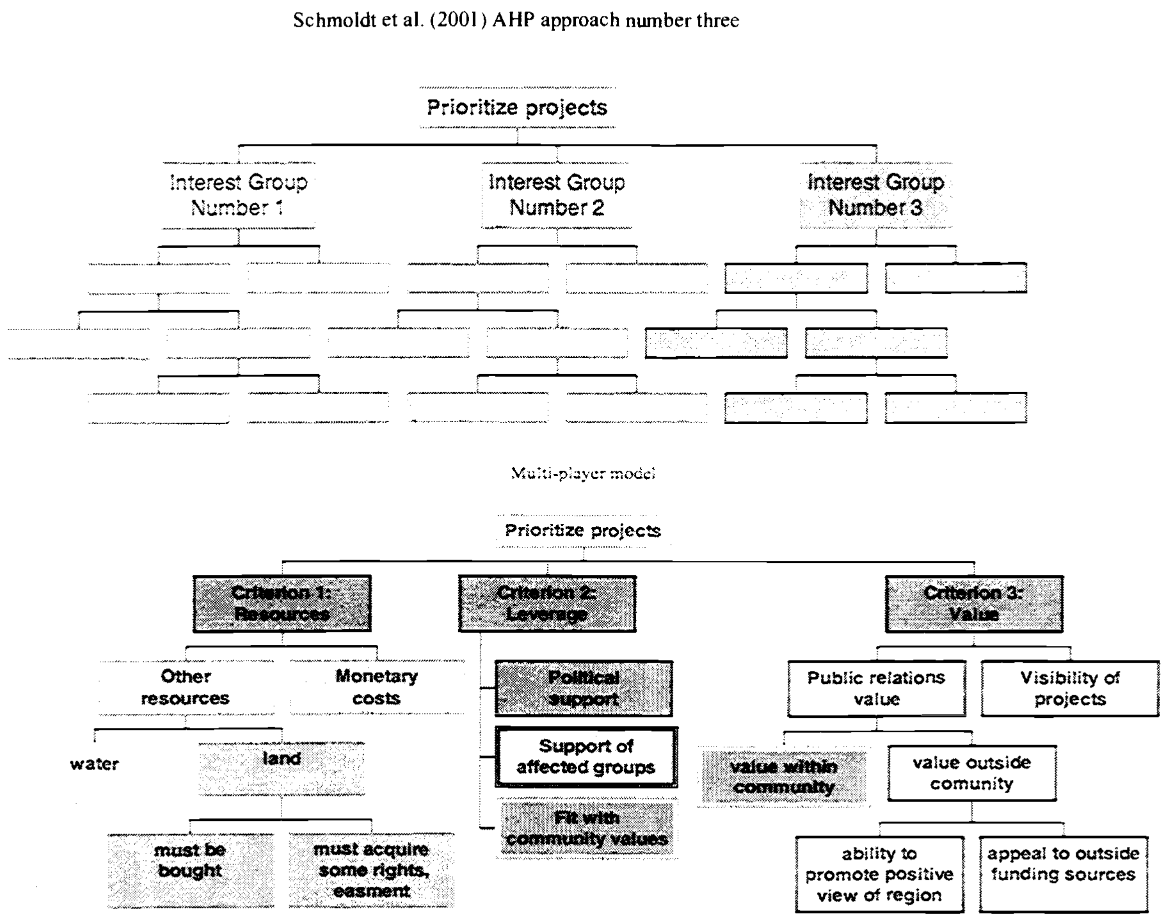

Figure 2. Comparison of Schmoldt et al.'s (2001) AHP approach number three and the multi-player model proposed in this paper. Like box styles represent criteria evaluated by the same set of decision makers.

criterion or those criteria about which they are concerned and knowledgeable. Each interest in the community is viewed as a "player" in the decision; however, the varying perspectives of these groups are not represented as alternative portrayals of the problem, as is the case with Schmoldt et al.'s (2001) third AHP model. Each player represents a group whose perspective on the project ranking is considered significant. All of the community interest is incorporated into one comprehensive vision, with players being represented only to the extent that their most important criteria are included somewhere within the model.

A semi-Delphic feedback process is used to reduce variation in the local priorities on any single criterion. Any remaining uncertainty and disagreement is evaluated using interval judgment (L. A. Bojorquez, personal communication 2002). Finally, as in Weistroffer et al. (1999), the primary decision makers, in this case the town council, will set criteria weights.

CONCLUSIONS

This preliminary examination of the Santa Cruz River corridor planning process AHP indicates that the analytic hierarchy process seems to fit well with the needs and expectations of Marana's planning staff. AHP is easy to understand and the staff is comfortable even given their limited exposure to the model. Discussions with a planning consultant have revealed that the process of developing an AHP hierarchy is forcing the planning staff to think more critically about the criteria to be included in the analysis. The effectiveness of this proposed model can only be evaluated after it has been applied to the problem of project prioritization. There are at least three potential measures of success. First, the multi-player model assumes that by restricting the individuals who participate in the generation of any set of local priorities to only those people who are knowledgeable about the criterion at issue, the amount of disagreement and uncertainty associated with any set of priorities will be reduced. If this is the case, then the probability of rank reversals among alternatives will be reduced and overall the results of the analysis will be more useful. This model also assumes that requiring participants to be knowledgeable about the areas for which they contribute preference information will also increase the consistency of the analysis. As noted earlier, lack of understanding is a primary cause of inconsistent analyses. An increase in the consistency would provide some evidence that the multi-player model is an effective approach. A final measure of success is an assessment of the extent to which effort on the part of decision makers has been reduced by using the multi-player model, as well as an evaluation of whether the time demands are sufficiently low for the model to be appropriate for real-world political decision situations.

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