Highlight

Active Response GIS: For Resource Management Spatial Decision Support Systems

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Abstract

The Active Response Geographic Information System (AR/GIS) is a toolkit for developing spatial decision support tools to help land resource managers in making and evaluating land resource allocation decisions. Although AR/GIS applications can be used in a stand-alone mode by a single resource manager, AR/GIS was originally conceived and designed to be a collaborative tool for interactive resource allocation negotiations conducted with a variety of stakeholders, or interested parties. It allows decision making groups to interact directly with geographic data and provides tools to evaluate resource allocation decisions made by individuals and the group as a whole. This paper describes the use of AR/GIS in a collaborative mode for land resource allocation decision making.

Introduction

Trends in land management point to increased community involvement in policy development and resource planning. Citizens are demanding a more active role in local decisions. Municipalities are seeking public input in defining and implementing legislative changes. In many cases, input from stakeholders is required to satisfy local and federal mandates. In this context, community representatives and planning authorities must often work together to consider alternatives for community design, determine economically viable options, and develop strategies which best address all concerns.

The success of the community decision making process often depends on whether:

- participating individuals develop an understanding and/or an appreciation of the many factors influencing the final decision;
- individuals feel that their concerns, objectives, and proposals have been considered;
- participants agree on decision criteria and priorities;
- adequate information is available to construct and assess the alternative solutions; and,
- rationale for decisions is preserved for subsequent justification.

The Active Response GIS (AR/GIS) is a toolkit for developing decision support tools which facilitate collaborative participant involvement in land planning. Currently operating in a "same place, same time" meeting environment, AR/GIS enables decision makers and stakeholders to effectively take advantage of collective knowledge in determining decision criteria and assessing implications of land planning alternatives in a geographic context. Future plans include expansion for development of applications which support "different place, different time" meeting environments using the Internet.

AR/GIS was developed by the Consortium for International Earth System Information Network (CIESIN) as part of a global environmental change assessment effort performed for the Agricultural Research Service of the US Department of Agriculture, with support from the Natural Resources Conservation Service, the Forest Service, the US Geological Survey, and IBM.

AR/GIS System Overview

AR/GIS is a Windows-based development toolkit that integrates GIS software with electronic meeting system software to facilitate negotiation of land resource allocation decisions between resource managers and other stakeholders. The AR/GIS collaborative tools are designed to operate on a local area network of linked laptop PCs. Figure 1 depicts the typical AR/GIS architecture consisting of participant laptops, a facilitator's laptop, a file server, a projection device, and other peripherals, such as a printer.

AR/GIS integrates two commercial software products, GroupSystems V electronic meeting system software (Ventana Corporation) and ArcView 3.0 geographic information system software (Environmental Systems Research Institute). GroupSystems V provides the electronic meeting system capabilities, including electronic brainstorming, consolidation and revision of brainstorming ideas, and electronic prioritization of ideas through a variety of voting mechanisms. Critical capabilities provided by GroupSystems V include:

- simultaneous input, allowing all participants to state their opinion or position on a given topic at the same time;
- anonymous input (if desired) which can minimize the effects of domi-

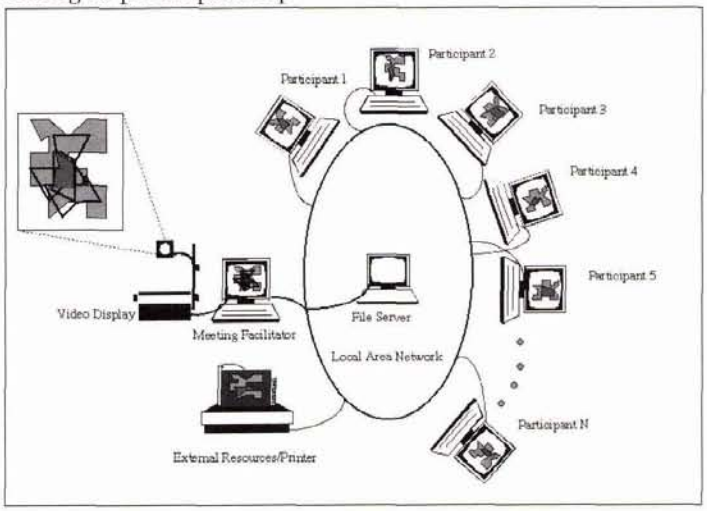

Figure 1. Electronic Meeting System Architecture.

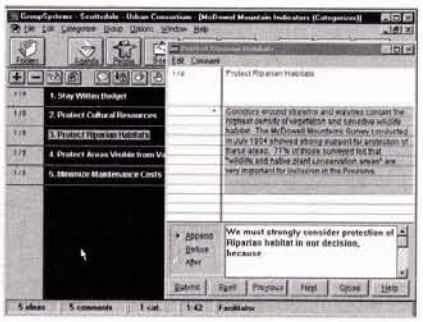

Figure 2. Use of GroupSystems V software to identify and define criteria to be used to evaluate proposals.

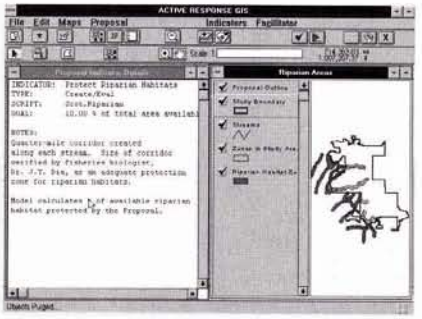

Figure 3. Creation of spatial definitions for evaluation criteria.

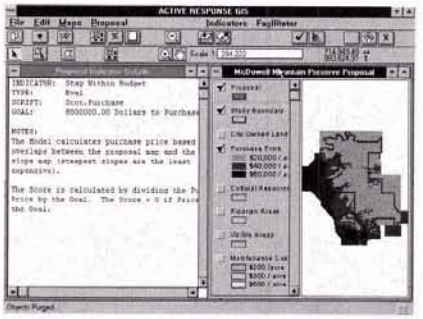

Figure 4. Development of models to evaluate land use proposals against defined criteria.

nant personalities and/or pre-established group hierarchies on the decision process;
- summarized display of all input for group review, and,
- automatically generated meeting documentation, available for review at any time.

ArcView provides the GIS software that allows participants to interact direct-ly with geographic data by reviewing data, drawing resource allocation proposals, and evaluating them. Prior to a planning session AR/GIS can be loaded with maps of the planning site and surrounding area, including structures, utilities, land characteristics, previous use designations, demographic distributions, etc. Other information might also be incorporated such as policy documents, cost estimate spreadsheets, economic impact models, and/or records of public concerns. AR/GIS can then make this information available to decision participants to supplement discussions throughout the decision making process.

Although AR/GIS uses ArcView 3.0 as a platform, AR/GIS adds an advanced level of functionality to ArcView which is specific to land use planning and collaborative resource modeling. These advanced capabilities include:
- efficient iteration between land use proposal development and proposal evaluation against group-defined criteria;
- on-screen sketching of land resource allocation proposals;
- storage and retrieval of individual and group proposals, and,
- spatial group negotiation tools for collaborative planning within a local area network configuration.

AR/GIS Application for Land Resource Planning

A typical application of AR/GIS in a collaborative decision making setting is illustrated through the following example, in which a municipality would like create a city-owned preserve in near-by foothills to prevent certain portions of this area from being developed. For this example, assume that a sales tax has been approved by voters which provides approximately eight million dollars a year to purchase land to be included in the preserve. The question to be answered by decision makers is what land should be purchased first and how should the "goodness" of various proposals be assessed. This application follows a specific structured process, as follows:
- Identify Criteria – Identify which criteria should be used in determining the "goodness" of a specific proposal for land use;
- Define Criteria — Develop a description of each criterion, and a spatial definition for each criterion, if applicable;
- Criteria Evaluation — Decide on a specific methodology for evaluating each criterion, including definition of an appropriate model, means of presenting results, and a finite goal or limit for each criterion;
- Criteria Ranking — Determine how important the individual criteria are in relation to each other;
- Proposal Development and Evaluation — allow individuals to develop land purchase proposals, evaluate these proposals, and develop a group proposal integrating the 'best" qualities of the individual proposals; and,
- Finalize Proposal — document final group proposal, including rationale for decisions made.

Criteria Identification

The electronic brainstorming capability provided by GroupSystems V allows participants to enter the criteria that they would like to see used to evaluate a land purchase proposal. Criteria can be identified are shown in Figure 2, and may include such things as staying within budget, protecting riparian habitat, protecting areas visible from major highways, etc.

Criteria Definition

GroupSystems V also allows participants to enter definitions for the criteria they have identified and to discuss and revise the definitions until the group is satisfied that the definition represents the group's concept of the criteria. Figure 2 also illustrates the textual definition of the "protect riparian habitat" criterion. Some criteria lend themselves to the development of spatial definitions if there are GIS data to support the development. The AR/GIS ArcView component provides the capability of developing these spatial definitions.

Figure 3 depicts the spatial definition of the criterion "protect riparian habitats." First the area

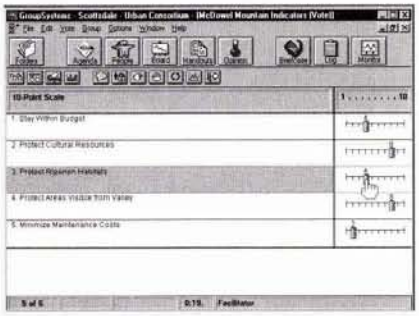

Figure 5. Use of GroupSystems V technology to rank evaluation criteria.

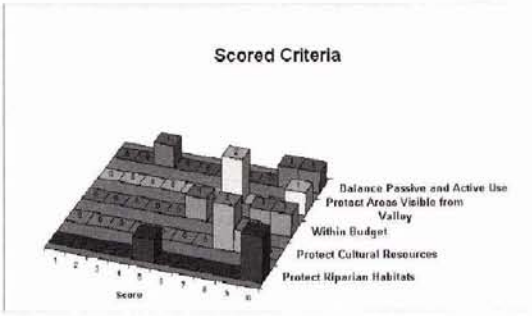

Figure 6. A visual representation of scored criteria allows participants to focus on areas of disagreement.

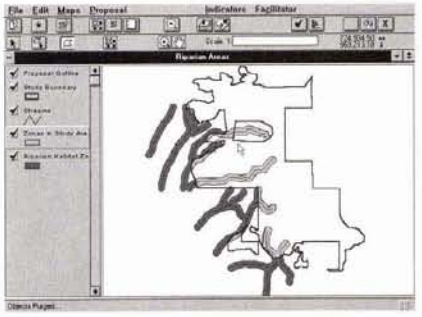

Figure 7. Participants individually develop land use proposals by sketching on the displayed landscapes. These can be collected via a local area network for group discussion, negotiation, and decision.

in which land is being considered for purchase is shown. This boundary is then overlaid with the streams from a GIS data layer. The group then can debate an appropriate corridor around each stream to define adjacent riparian habitat. Similar spatial definitions can be developed for the "protect cultural resources," and "protect areas visible from the valley" criteria using GIS data showing important areas, such as petroglyphs, scenic overlooks, etc., and viewshed analyses, respectively.

Criteria Evaluation

Through a combination of discussion and use of the electronic meeting system technology, participants can decide on a model to be used to evaluate each criterion for a given land purchase proposal. In this example, models are relatively simple, although more complex models can be used if the group agrees that they are necessary. An important factor in selecting fairly simple models is that evaluation results can be made available to the group in real-time (generally less that a minute). More complex models delay the feedback to the group.

For example, to evaluate whether a specific proposal was within the eight million dollar budget or not, a simple model was used that defined purchase price for an acre of land based on its slope, with the steepest land being the cheapest, as illustrated in Figure 4. Using the three slope categories, derived from a digital elevation model, and resultant purchase price, the cost of a specific proposal can easily be calculated and compared to the budget goal.

Criteria Ranking

Since the criteria are developed by individual participants, all criteria may not be equally important to all participants. In order to make tradeoffs as part of the decision making process, it is important to have a group consensus as to the relative importance of each criterion. GroupSystems V provides a variety of voting tools to assist the group in the ranking process. Figure 5 illustrates the use of a "sliding scale" mechanism to allow each participant to "score" the criteria according to their own idea of what is important.

Once all participants have cast their vote, AR/GIS will provide an aggregate score for each criterion as shown in Figure 6. Looking at the vote visually enables participants to focus on areas where there is disagreement, such as the spread of the vote on the "protect riparian habitats" criteria. With the help of the facilitator, the group is usually able to reach a consensus on the criteria ranking.

Proposal Development and Evaluation

AR/GIS provides individual participants the capability to draw a specific land purchase proposal on a map of the area. Participants can select the view upon which they want to draw their proposal. For example, one participant may elect to draw their proposal on the riparian habitat view as shown by the polygon drawn in Figure 7. Others may want to sketch their proposal on the cultural resources view, or the viewshed view, or the purchase price view. A sketch drawn on any view is replicated on all other views.

Once a participant has drawn a land purchase proposal, AR/GIS provides the capability to evaluate that proposal against any or all of the criteria using the evaluation models and goals previously defined. Results of the evaluation are provided as shown in Figure 8.

Based on the results of the evaluation, the participant can decide to erase the proposal and start over or modify the existing proposal. This is an iterative process that continues until the participant is satisfied that their proposal is the best they can devise.

Each participant's proposal becomes a GIS data layer that the facilitator can use to create an overlay showing areas of agreement among the participants, as shown in Figure 9. This can form the basis for reaching a group consensus proposal by creating a new proposal based on combining the areas where there is greatest agreement among the participants. This new proposal can then be evaluated and modified in an iterative process until the group is satisfied with the result.

Final Proposal

The final proposal can be saved as a GIS data layer and can be used to generate a variety of documentation about the proposal. All material generated as a result of the steps described is also available as part of the final proposal record.

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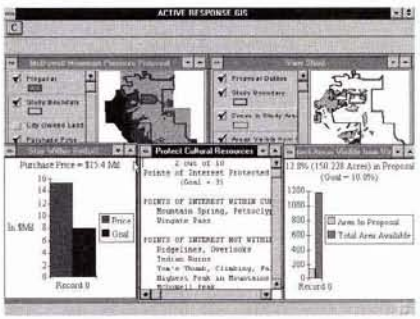

Figure 8. Display of criteria evaluation for a given land use proposal.

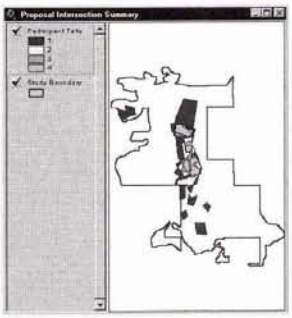

Figure 9. Overlay of individual proposals to highlight areas of agreement and disagreement among the participants.

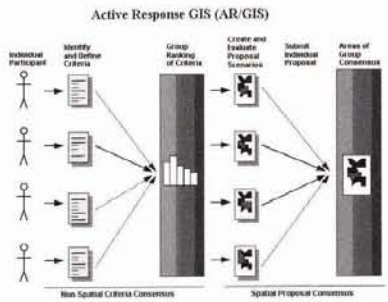

Figure 10. AR/GIS group negotiation tools provide support for both individual input and consensus analysis.

In addition, AR/GIS provides a "notepad" capability that allows participants or the facilitator to enter notes about any of the intermediate proposals or the final proposal. This provides an "audit trail" that can document the rationale for the final decision as well as any intermediate decisions reached by the group.

Other AR/GIS Applications

AR/GIS has been successfully applied in a number of other projects involving resource management, sustainable development, site remediation, and public involvement. Projects include:

- *Arapaho-Roosevelt National Forest* — Multi-participant resource management system and interactive kiosk for management plan review, public comment, and public values mapping.
- *Denver Smart Places (Stapleton Airport), Colorado* — Interactive urban design system incorporating energy, waste, water, and transportation modeling.
- *US Forest Service Pacific Northwest Research Station, Oregon* — Pilot project demonstrating public participation in policy analysis and adaptive management planning.
- *US Department of Defense, Hawaii* — Prototype decision support tool for remediation planning
- *Natural Resources conservation Service (NRCS), Nebraska* — Collaborative system for inter-agency alignment of ecoregion definitions and boundaries

Although the underlying capability is similar across all these projects, each AR/GIS application is tailored to meet project-specific objectives. Each application features a customized interface design and extended function to best address a unique audience.

Summary

AR/GIS provides the capability to integrate individual participant input, both spatial and non-spatial into a group decision, as shown in Figure 10. AR/GIS is applicable to a wide range of land resource allocation issues in both urban and natural resource settings, and is particularly useful in decisions and negotiations where input from a variety of stakeholders is either required or desired. Our cumulative experience with all AR/GIS projects performed to date is that AR/GIS provides a powerful tool that:

- facilitates decisionmaking in a spatial context for non-technical persons;
- shortens the time frame for decisionmaking by allowing decisionmakers to interact directly with geographic data rather than having to rely on GIS technicians;
- provides realtime feedback to decisionmakers on the impact of their decisions and provides an iterative process to get to the "best" decision;
- allows for community participation in the decision process so that all parties can feel that they "own" the final decision; and,
- Provides an audit trail of the decision process so that decision rationale and justification are readily available.

Acknowledgements

AR/GIS was developed by the Consortium for International Earth System Information Network (CIESIN) as part of a global environmental change assessment effort performed for the Agricultural Research Service of the US Department of Agriculture, with support from the Natural Resources Conservation Service, the Forest Service, the US Geological Survey, and IBM. Applications described in this paper were developed with the support of the City of Scottsdale, the Denver Smart Places Project, and the Arapaho-Roosevelt National Forest. For further information on CIESIN and AR/GIS, see URL http://www.ciesin.colostate.edu/ARGIS.

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