DISCUSS: A soft computing approach to spatial disaggregation in economic evaluation of public policies

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Abstract: For more than three decades cost-benefit analysis (CBA) has been used in many countries as an important tool for evaluating public policies. More recently, participation of stakeholders in CBA processes has become an important issue for governments. However, CBA by itself does not provide a good environment for stakeholder participation. A major reason for this is the lack of spatial disaggregation in traditional CBA. In order to allow greater public participation, a GIS based approach is proposed. This approach uses a Geocomputational system, which incorporates soft computing theory with expert systems in a geographic information systems (GIS) environment. It is designed to generate representations of environmental, economic and social policy outcomes according to the perceptions of the stakeholders and after the CBA results have been obtained. The methodology proposed for modelling impacts in cases where uncertainty exists uses the soft computing theory of fuzzy logic to generate a raster map based on spatial inputs provided by the stakeholders involved in the decision process. This computer based system, called DISCUSS (Decision Information System for Community Understanding of Spatial Scenarios), is intended for situations where the government chooses to evaluate a policy using CBA and desires to encourage public participation in evaluating the results identified by the economic methodology. DISCUSS and the maps that it produces are being tested in a public participation case study with long-term impacts over a large area of south-eastern Australia.

Keywords: Public participation, Cost-benefit Analysis, GIS, Soft computing, fuzzy logic

1. INTRODUCTION

In recent years, public participation in decision processes has become an important issue for governments not only to satisfy the requirements of the multinational plan of action Agenda 21, but also to ensure the success of the option selected in the long term (Ball, 2002).

At the same time, and despite many controversies, cost-benefit analysis (CBA) is still a common methodology for evaluating policy or project options and for selecting the best decision for society. Posner (2001) demonstrated, using a search in the Westlaw in the Federal Resister database, a continuous increase since 1980 in the total number of CBA reported to the Federal Register in the United States of America. Moreover, the popularity of CBA has spread in some cases from central governments to states (Hahn, 2000), proving that the controversy surrounding its validity has not affected its popularity at different government's levels. Although it is not applied in all decision processes, CBA is still considered a powerful and valid tool because it allows comparison of monetary and non-monetary costs and benefits for each of the alternatives by converting all the effects of the options into monetary terms (Farrow and Toman, 1999). This allows decision makers to generate a single value for each option that represents the benefit for that particular option for the society.

However CBAs and the results that they generate are not widely understood (Heinzerling and Ackerman, 2002). Also, CBA results do not have, by themselves, a clear spatial component. This makes it difficult for communities to understand who is going to be affected and where impacts might occur. Therefore, public participation would be limited unless an additional public participation process is undertaken after the CBA results have been obtained.

Considering that CBA is a methodology still used for many decision process in developed and developing countries and to address participation difficulties arising when CBA method is chosen, we developed the computer software and associated approach called DISCUSS (Decision Information System for Community Understanding of Spatial Scenarios), which is based on a Commercial GIS product.

The main purpose of the system is to support the decision process by facilitating interaction of stakeholders with the results generated by CBA. The users of the system (which in most of the cases are the stakeholders of the decision-process) plot polygons in a map that represents the different areas which will be affected according to their different opinions. We call this process of transforming the economic numerical results from CBA into a map representation "spatial disaggregation".

The main output of the system is the identification of the disagreement between stakeholders in terms of spatial location of effects of the policy. This identification of differences could be done individually for each stakeholder or by grouping them in accordance with their similarities.

In the first part of this paper we explain CBA methodology and the limitations that it might have when it is used in a public participation process. Our interest in this section is not to justify the use of CBA in decision process, but to denote the public participation difficulties that CBA presents when it is applied in policy-making.

Then we explain the different characteristics of DISCUSS, the computer software. We also include an explanation of the methodology that we believe could be followed in order to use DISCUSS.

After explaining DISCUSS, we examine the results of our case study, Lake Mokoan, where DISCUSS was used to interpret the public submissions made after the CBA results were achieved.

Finally, we present our conclusions about the system and the experience with DISCUSS in the case study. Alternatives for future work with the system and in the public participation area are proposed.

2. COST-BENEFIT ANALYSIS IN A PARTICIPATIVE DECISION PROCESS

2. 1 Introduction

A normal practice in the art of governing is to generate policies that are believed to be beneficial for the society. Different alternatives are then developed and evaluated using in most cases economic methods, such as CBA. Many authors have recognized that CBA cannot be used in all decision situations, especially where significant effect do not have a clear monetary value (for example (Marshall and Brennan, 2001) and (Boardman, 2001)). However, this methodology is appropriate in those cases where a good economic estimation of environmental, social and economic effects can be achieved. In this section we will explore how CBA operates in a real environment and identify the obstacles that CBA presents to public participation.

2. 2 Cost-benefit analysis (CBA)

After a government proposes a new policy, the next step is to generate the different alternatives by which to achieve the goals. In many cases, these alternatives involve projects that modify or construct public infrastructure and affect the environment.

The next action is to evaluate the alternatives. For this purpose, one economic method is CBA. Numerous books and articles have complete definitions of CBA methodology (Boardman, 2001), (Dorfman, 1997), (Fuguitt and Wilcox, 1999). For present purposes, CBA is described as a four steps process following Farrow and Toman (1999).

The first step is to define a baseline for the situation in which there is no change (a scenario where the policy is not applied). This provides an overview of the current situation and the implications of not implementing the policy. The second step in a CBA involves identification of the different alternatives for implementation of the policy. With a complete picture of the alternatives, the third step involves identification of the differences over time between the policy scenarios and the baseline scenario. This identifies the benefits and costs of the policy options. This third step often involves multidisciplinary skills to determine the full effects.

The fourth and final step involves assigning those benefits and costs a monetary value. Some benefits and costs may be estimated in monetary terms (e.g. the construction cost of a road or the incomes from a toll) from the beginning. However, some costs and benefits for society may not normally be reckoned in monetary units (e.g. the changes in noise levels for residents near the road). Therefore, it is necessary to assign a monetary value to them. To do this, multiple technical methodologies are used. These provide an estimation of the effect in terms of financial benefits or costs (e.g. changes in real-estate values because of the road noise). Finally, with these results, an aggregation of the effects over time is done.

In some cases, and in order to improve the reliability of CBAs, further sensitivity analyses are developed to determine how robust the results in the model are and to produce qualitative information on monetised benefits and costs (Farrow and Toman, 1999).

The main outcomes of a CBA for decision-making are indicators. These indicators are numbers and percentages that represent the net benefits that the community or society will receive if the particular alternative for the policy is implemented. They represent a picture of the amount (or monetary value) of the benefits of a policy alternative for the society. This amount is calculated for a fixed period of time, which in most cases is 20 years.

2. 3 Public participation after CBA

In order to encourage better support for their decision, governments are increasingly promoting more public participation in the decision process. If we consider a scenario in which scientific veracity might not be guaranteed and people are differentially affected, consensus might only be obtained by a public participation processes linking the communities with the environment or infrastructure changes in question (Ball, 2002).

Public participation could occur in multiple phases of the decision process. In developing DISCUSS, we concentrate on the public participation that occurs after the results from the CBA are achieved.
In these cases, governments often open the final report produced by the technical advisors for discussion and allow public participation by submissions of comments. These comments are then summarized.

Some difficulties are apparent when decision-makers are searching for public involvement with the CBA results (Paez et al., 2003). These justify the development of a new approach and soft computing system (DISCUSS).

One problem is the reliability of the technical models (environmental and social) used to predict the different effect of the policy alternatives. Cortner (2000) argues that there is no truly objective science. While many may argue with this, subjectivity is clearly a factor when complex environmental and social interactions are involved. Farrow (1998) indicates the difficulty of estimating benefits from improvements in environmental quality because their values must be inferred from indirect evidence. This is crucial because, among other factors, the credibility of the CBA depends on the rigor of these estimations (Nigro, 1984).

Consequently, stakeholders understand that subjective judgements are part of the scientific process during the CBA. This makes it possible for a particular stakeholder to argue that a model or prediction could have some bias for a specific community or region, or even for a policy alternative. Also, stakeholders are unlikely to trust any output from a technically complex model.

Another issue concerning the credibility of CBA is its complexity. Significant economic knowledge is required to understand the procedures behind the generation of indicators for decision-making.

Finally, and most importantly, few CBA results present a spatial representation of the benefits and costs. The indicators produced in a CBA do not show who is going to be affected or where the positive or negative impacts may occur. This is a very important issue in CBA for governments. An important example is the USA Executive Order 12866 (OMB, 1996). This presidential document requires economists not only to present an evaluation of the value of benefits and costs, but also spatial references to the effects estimated for each of the options. Despite the demand by decision-makers for spatial disaggregation, this is a highly complex process requiring considerable effort if current practices are used (Morgenstern, 1997).

In conclusion, in many cases of public participation in CBA, the stakeholders have to interact with technical models that they might not understand and with economic methodologies that produce results that are difficult to comprehend. These difficulties tend to focus discussion on the methods and procedures used during the CBA and not on the alternatives proposed, creating environment in which consensus is difficult to build.

Therefore, DISCUSS has been designed as a GIS based system for promoting a better public participation in the CBA process by providing a simple approach to modelling spatial disaggregation of public input. We believe the application of this software, after the CBA results are achieved, aids the interaction between communities and governments; and at the same time helps decision-makers to identify disagreement between stakeholders. This facilitates the decision process because more people (with different backgrounds) can better understand the economic analysis and, therefore, participate actively in the discussion of alternatives.

3. DISCUSS: a decision support system when CBA is used

3.1 Characteristics of the software

When designing DISCUSS we initially intended to create a tool capable of disaggregating, in a technical form, all the results from a CBA. However, after analyzing the decision process, in which facts are seldom known completely and merge with opinions, we preferred a tool that facilitating the input of stakeholders' opinions of spatial costs and benefits to pinpoint areas of greater disagreement between stakeholders. Ideally, the system should provide for both spatial disaggregation on the basis of scientific models (where available) and the softer or subjective disaggregation of stakeholder opinions.

In order to facilitate this interaction with opinions and scientific knowledge we have decided to incorporate into our system a soft computing approach. DISCUSS uses fuzzy logic theory in order to acquire the judgments from stakeholders and experts. This kind of computing is called "soft" because it allows inputs to be neither true nor false. Instead, the input could be of different levels using verbal qualifiers. A very comprehensive description of soft computing methodologies and fuzzy logic can be found in (Openshaw and Openshaw, 1997)

Governments recognize the usefulness of a methodology facilitating involvement of different parties and delivering a sense of ownership (Stewart, 1993). The focus of DISCUSS is, therefore, to allow users to spatially interact with the CBA results presented, generating a sense of ownership of the policy and its alternatives. DISCUSS is based on a geographic information system (GIS) and combines concepts from Planning Support System (PSS), Expert system (ES) and Decision Support System (DSS). DISCUSS was created by programming additional functions in Visual Basic for Applications (VBA) under ArcMap, which is a GIS software produced by ESRI.

A PSS links a variety of computer-based software to support decisions at different stages of the planning process (Batty and Densham, 1996). DISCUSS cannot be characterized under this title completely. This is principally because the system is not for use throughout the decision process. Alternatively, DISCUSS could be categorized as an Expert system (ES), also called knowledge-based systems by some author. The module that generates new spatial indicators for decision-making contains one of the principal characteristics of these systems: the ability to replicate certain aspects of expertise (Jun, 2000). However, not all results are based on expert knowledge. The system is flexible in combining soft information and hard information (Malczewski, 1999) according to the data available.

DISCUSS can be considered as a DSS under the concept develop by Pereira and Quintana(2002). They describe DSS as a context and platform for helping all those involved in decision-making to access the policy information needed to stimulate useful debate. An example of DSS with a similar approach is GOUVERNe, created for groundwater governance issues (Quintana et al., 2002) Consequently, we regard DISCUSS as a

DSS that incorporates elements for revaluation within the planning process and, in some modules, operates as an expert system.

3.2 Use of DISCUSS

DISCUSS can be used in different ways in accordance to the decision process. It can be applied as direct tool for interacting with the stakeholder in a workshop environment or can be used as a tool for the decision makers to organize, visualize and analyse the input from the community. We have identified three stages in the required methodology to apply DISUCSS: input CBA results, disaggregation of effects and generation of new analysis for decision making.

Stage 1: Input CBA into DISCUSS

The main purpose of a CBA is to distinguish different options for a policy. Therefore, the first step using DISCUSS is entering the results from the CBA for each option. DISCUSS contains a module called 'OPTIONS CONSIDERED' where all the information regarding the monetary benefits and cost can be entered.

If the decision process is having direct input from stakeholders, step one is their opportunity to modify the options or add new ones. Although DISCUSS permits 20 different options, it is recommended that no more than 5 be used in the analysis if direct interaction with stakeholders (in a workshop environment) is intended. In some particular case where the tool is used for internal support of the government process, numerous scenarios can be handled effectively.

Additionally, we consider that only those effects (positive and negative impacts) where stakeholders are expected to have varying opinions about the spatial effects and at the same time have an important contribution to the net flow should be added to the analysis with the stakeholders. Probably only those effects with a value over 20% of the total estimated cost for the project should be considered.

We acknowledge that some effects that lack a clear spatial representation could have an important influence on the discussion. DISCUSS is not appropriate for these benefits or costs and other methodologies for public discussion should be explored.

In addition to the CBA results, technical information about the spatial representation of effects could be added in step one of the methodology. This means, for example, that if an environmental model that is capable of producing a representation of the areas affected was used during the CBA to calculate a certain effect, this layer can be added to the analysis. DISCUSS accepts only raster inputs for this technical representation and the sum of the value of all the impacted cells should be equal to the total monetary value calculated for the impact. For those cases where the model results are not in the format required, users can use the GIS tools in ArcMap, the basic platform for the system, to bring the results into DISCUSS format.

Stage 2: Disaggregation of effects

Once all the scenarios and their effects (costs and benefits) are entered in DISCUSS, the next stage is to spatially disaggregate the effects. This requires assignment of an area or space to where its impact is considered most likely to occur to each cost and benefit. This process is done individually for each stakeholder and can be done in a workshop environment or by an interpreter of written submissions from the stakeholders.

This requires understanding stakeholder's perception of the scenario and its spatial impact. Consequently, in stage two every scenario and effect is manipulated individually for each stakeholder. To do this, DISCUSS opens individual files for each stakeholder. The process could be done for all the stakeholders at the same time if several computers are connected by a network.

For example, if 10 stakeholders are included in a process with 3 possible options and at the same time an average of 10 effects (benefits and costs) for each option, 300 individual representations (10*3*10) of effects will be generated by DISCUSS. In stage 3, which we explain later, we propose aggregation methods of the individual representations to produce a general perception of the stakeholders about the different options.

During stage 2, DISCUSS provides three methods to disaggregate the benefits and costs: Technical disaggregation, disaggregation to geographic entities and fuzzy disaggregation.

Technical Disaggregation

During stage one, it is possible to input to the system technical representations available for the effects. The stakeholders individually can accept, modify or reject this technical representation. Operationally, the system will show to the user effects with a technical representation and ask the stakeholder to accept, modify or reject these representations.

If the stakeholder accepts the technical representation, this is automatically assigned for that particular effect and the stakeholder can move to the next effect in the scenario. If he or she desires to modify the technical results, the system converts this technical result from the model into a polygon map by reclassifying it into four classes and then converting the result into a vector map. The map created constitutes a start point for using the "Fuzzy Disaggregation method" that we explain later.

If the user does not accept this original technical representation at all, DISCUSS allows the stakeholder to apply the next method "Disaggregation to geographic entities" for the same effect.

Disaggregation to geographic entities

In some circumstances, stakeholders consider that some geographic entities, such as local government areas, census collection districts, municipalities, postal codes or electoral boundaries, could better represent the area that will be affected. In this case, for each benefit and cost, users may assign the benefit to one or many polygons. The number of geographic entities available for this type of disaggregation depends on the spatial data infrastructure available for the concerned area and its configuration in DISCUSS. To allow this type of disaggregation, before the system is used by the stakeholder, the desired layers must be added to the system.

To use this method, users select one or many polygons and assign them a monetary value. This amount can be assigned by percentage or by monetary value. If after finalizing this disaggregation method the total amount assigned by the stakeholder is not equal to the amount available for the effect according to the characteristics of the option, DISCUSS adjusts this value in such way that all the monetary value is represented in the space. For instance, if the monetary value of the effect is $10 million, and the user only assigned to the different polygons $9 million, the difference – $1 million- is distributed by adding a proportional value to each polygon selected from the available layers.

Fuzzy Disaggregation

If the previous method is not accepted for some effects, the third and final alternative for stakeholders to spatially distribute effects is by a method that incorporates fuzzy logic. Our desire with this method is to allow users to make a fuzzy input to the system and get a crisp mapping as a result.

In this method stakeholders have more flexibility to disaggregate effects than in "disaggregation to geographic entities" because they are not restricted to polygons from another database. Stakeholders create their own areas of affectation with this method.

To apply this method to a specific impact, the user has to draw onto a base map polygons which correspond to the different levels of impact. The user has to draw at least two sets of polygons. One set should represent those areas which are considered to have the highest level of impact. The other set should represent areas which are definitely considered to have no impact.

If the user only inputs the basic two datasets (areas with impacts and areas with no impacts) the system will generate a linear distance interpolation. If necessary, the system can also generate nonlinear distance interpolations for the stakeholder to choose from.

In addition to these two sets, stakeholders can create as many sets as they want, with a different level of impact. This allows users to tell the system where different levels of impact occur in a scale from 0 (no impact) to 1 (completely impacted). If at the end of the process the entire "area of influence" is covered, DISCUSS assigns impact according to the weighting given. In this case, no fuzzy logic is used and direct weighting of areas are used to assign the effect.

However, if not all the area for the project is covered by the stakeholder, and some area where impact is uncertain exists, DISCUSS will calculate a fuzzy number for each cell affected by uncertainty. These fuzzy logic numbers are created using the distance of each cell from all the nearest polygons with different levels of impacts.

Figure 1 represents the distances d_1 and d_2 that DISCUSS will use to generate the fuzzy number for the cell *A* according to its proximity to the two zones with level of impact y_1 and y_2. This level of impact could be a number between 0 and 1.

Figure 2 shows the graphical representation of the fuzzy logic membership function for the cell *A*. The x-axis represents the distance from cell *A* to the zones with level of impact y_1 and y_2. The y-axis is the degree of membership.

For each individual cell the fuzzy numbers are combined. Finally, a crisp value is generated for all the cells using the "centre of gravity" method for defuzzification (Yager and Zadeh, 1992).

Stage 3 Assembling concepts

Following the disaggregation of the different effects (benefits and costs) for all the different scenarios proposed for the policy or project, the third stage in DISCUSS is to aggregate all these inputs from the stakeholders into a consolidated result.

To assemble this map showing different impacts, DISCUSS calculates different options for agreement and disagreement between stakeholders. For example DISCUSS can calculate the standard deviation or the maximum different between cells from the inputs from stakeholders. This makes it possible to see the areas where greater difference between stakeholders occurs.

Using spatial algorithms for clustering, it is possible also to generate groups of stakeholders with similar perceptions. These groups could then be compared with individual stakeholders and DISCUSS can also present a map for each stakeholder for an individual scenario, producing a spatial representation of the indicators for decision-making. Individual results from stakeholders can be combined to produce a consolidated map.

In addition to the proposed aggregations in DISCUSS, the user can generate more alternatives with standard tools available in the GIS. This is possible because all the results in DISCUSS are in a raster form, allowing manipulation using spatial statistics.

With these aggregations, DISCUSS presents to the decision makers and the stakeholders an overview of the different perceptions about the project options.

4. CASE STUDY: Lake Mokoan

In the state of Victoria - Australia, the water industry is in a mature phase where resources are largely developed and committed to existing users (SKM, 2000). Therefore, when the Victorian government decided to analyse a policy for achieving significant water savings in the northern part of the State, a detailed analyses of different alternatives was needed. Each possible option would impact positively on some regions and negatively on others. This made it an ideal case study to trail DISCUSS because any alternative to save water in the system involved different perceptions of effects from a wide variety of stakeholders.

The government decided to contract a consultant company to analyse the different alternative for saving water in the State of Victoria. The firm Sinclair Knight Merz (SKM) was contracted and conducted preliminary studies for evaluating alternative water saving policies. In these preliminary studies, the main options for saving water were determined. Changes to Lake Mokoan produced the largest net water saving (SKM, 2002). Lake Mokoan is a hand-made water saturate and, among other alternatives, returning Lake Mokoan back to a wetland and reducing its current capacity as a lake were identified as key options to achieve water saving in the system.

With these results, the Victorian government decided to contract a more detailed study to analyse the possibilities for Lake Mokoan. The final results of this study included a detailed analysis of the possibilities for Lake Mokoan and a CBA for all the possible alternatives for the lake. Using common practice, the government published the final results of the study and established a specific period for submission of public comments about the results of the study. These results were then processed to produce a table containing four columns: the description of the issue, the comment from the consultant firm, the number of submissions addressing this issue and a reference to the final report where the issue was addressed.

In this section we present the results using DISCUSS with the Lake Mokoan case study. We used DISCUSS to transform the table (or summary) of submissions into maps that represent the different perceptions of spatial impacts..

From this process of disaggregating the submission from stakeholders we found:

- An important number of submissions did not have a clear spatial component. The community expressed their agreement or disagreement to the option without mentioning a specific area they considered affected. These submissions cannot be treated with DISCUSS. The second phase of the case study will facilitate consideration of these submissions during interaction with stakeholders in a workshop
- Another difficulty was that some submissions identified a spatial component, but it was not related to a specific scenario studied in the CBA. For these cases individual results were generated, but aggregation between stakeholders was not possible.
- On the other hand, some submissions permitted a clear interpretation of the scenario considered and the area affected. With these community submissions it was possible to generate a map showing the areas affected by disagreement between stakeholders. Among these, four areas showed not only disagreement between stakeholders, but also between the perception of the technical advisors and the community.
- “Changes in land value” is an example of an impact where disagreement between the technical advisors and stakeholders exists. This effect is included on the CBA of the option 1 “removing lake Mokoan of

the System”. Figure 3 is the spatial disaggregation using DISCUSS of the stakeholder perception for this particular impact. Figure 4 shows a map of the perception of the technical advisors for the same impact.

- Figure 5 represents the areas of agreement and disagreement between the stakeholders and the technical advisors. This map was created with DISCUSS and it is an example of the output of the system. It is expected that this type of result helps decision-makers to focus their negotiation efforts in the areas where more discrepancy exists.

5. CONCLUSIONS

As a result of our work with the Lake Mokoan case study we found that it is important to input the information from the stakeholders into DISCUSS with the correct spatial characteristics. For this, it is especially significant to encourage stakeholders to include spatial references to their comments, so most of the analysis features included in DISCUSS can be used.

In the submissions, the majority of the attention was not focused on any particular option, making it difficult to identify the areas where more discordance exists. Therefore, it could be useful for the decision process in Lake Mokoan to develop a workshop activity, where interaction between stakeholders and DICUSS is achieved.

We have adopted the concept, proposed by Quintana et al. (2002) that a DSS should help decision processes by promoting a better environment for discussion. We believe that decision processes cannot easily achieve an acceptable technical solution for every stakeholder. To facilitate negotiation, we propose a methodology for public participation in which the main outcome is the identification of the issues that divide the opinions of stakeholders. DISCUSS is a tool that can represent these differences in a map form enhancing the participation process. In this context, our results with Lake Mokoan exposed to the decision-makers the factors and areas that are causing the community to reject the project. The next step in the decision process will be to concentrate the discussion on these areas and effects.

Kinston et al (2000) showed that the Internet can be an important tool for public participation. Therefore, another development of DISCUSS is to convert it to an Internet based application. This would allow a broader participation from the stakeholders and at the same time may lead to a reduction in costs associated with the decision process.

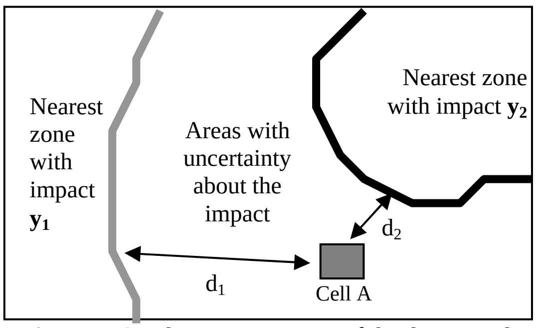

Figure 1. Graphic representation of the distances d1 and d_2 used to create the fuzzy number for the Cell A

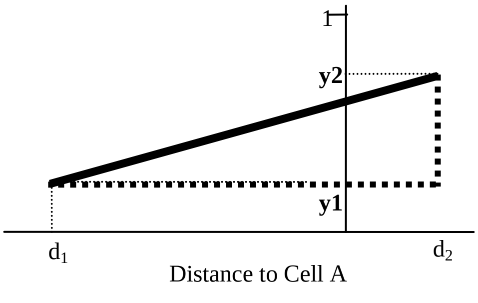

Figure 2. Membership functions for the cell X.

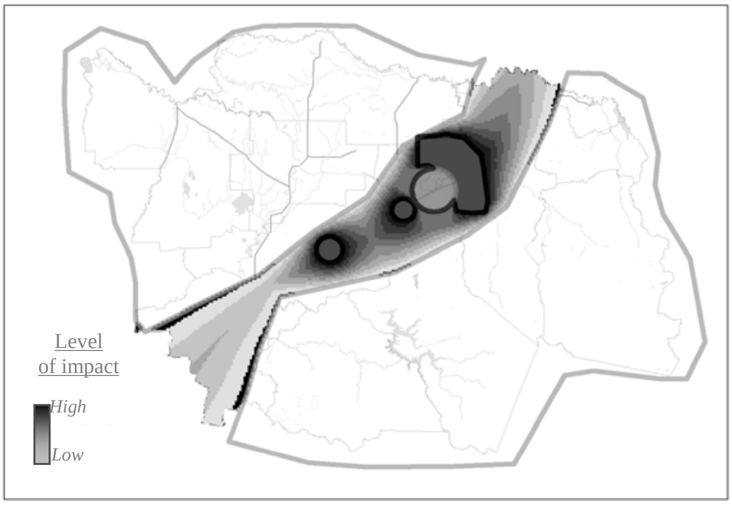

Figure 3
Spatial disaggregation using DISCUSS of an stakeholder perception. In this case the impact is "Changes in land value"

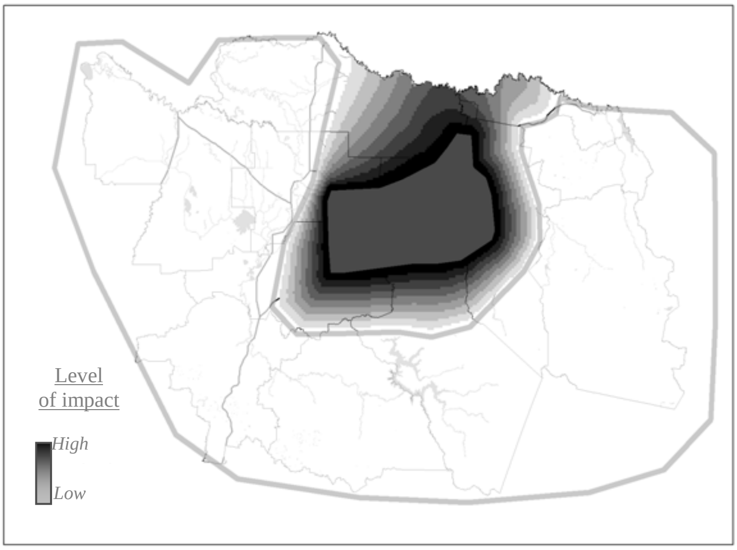

Figure 4
Spatial disaggregation using DISCUSS of an stakeholder perception. In this case the impact is "Changes in land value"

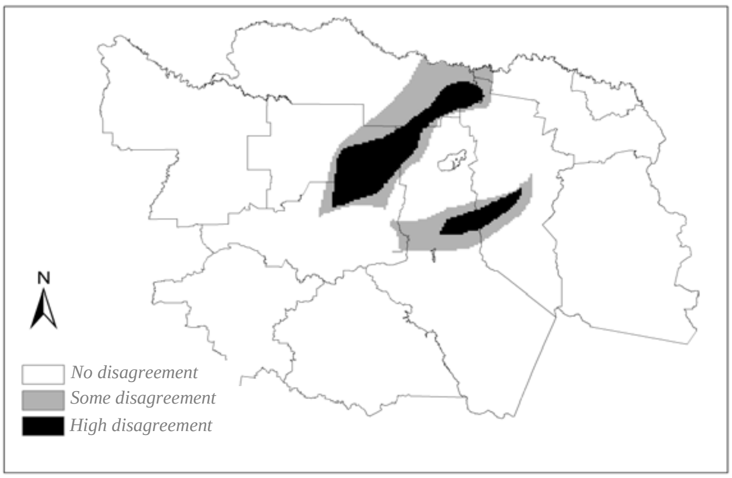

Figure 5
Areas of agreement and disagreement between the stakeholders and the technical advisors

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7. REFERENCES

Ball, J. 2002 Towards a methodology for mapping 'regions for sustainability' using PPGIS. *Progress in Planning* 58**,** 81-140.

Batty, M. and Densham, J. 1996 Decision Support, GIS and Urban Planning. WWW document, www.geog.ucl.ac.uk/~pdensham/SDSS/s_t_paper.html

Boardman, A. E. 2001, *Cost-benefit analysis : concepts and practice* Prentice Hall

Cortner, H. J. 2000 Making science relevant to environmental policy. *Environmental Science & Policy* 3**,** no. 1 21-30.

Dorfman, R. 1997, *Economic theory and public decisions : selected essays of Robert Dorfman* Edward Elgar

Farrow, S. 1998 Environmental equity and sustainability: rejecting the Kaldor-Hicks criteria. *Ecological Economics***,** no. 2 183-188.

Farrow, S. and Toman, M. 1999 Using benefit-cost analysis to improve environmental regulations. *Environment* 41**,** no. 2 12.

Fuguitt, D. and Wilcox, S. J. 1999, *Cost-benefit analysis for public sector decision makers* Quorum

Hahn, R. W. 2000 State and Federal Regulatory Reform: A comparative Analysis. *Journal of Legal Studies* 29**,** no. 2 873.

Heinzerling, L. and Ackerman, F. 2002, 'Princing the priceless' Georgetown University Law Centre, Washington, D.C.

Jun, C. 2000 Design of an intelligent Geographic Information System for Multi-criteria Site Analysis. *URISA Journal* Vol. 12**,** no. No.3 5 - 17.

Kingston, R., Carver, S., Evans, A. and Turton, I. 2000 Web-based public participation geographical information systems: an aid to local environmental decision-making. *Computers, Environment and Urban Systems* 24**,** 109-125.

Malczewski, J. 1999, *GIS and multicriteria decision analysis* J. Wiley & Sons

Marshall, G. and Brennan, J. 2001 Issues in benefit-cost analysis of agricultural research projects. *Australian Journal Of Agricultural And Resource Economics* 45**,** no. 2 195-213.

Morgenstern, R. D. 1997, *Economic analyses at EPA : assessing regulatory impact* Resources for the Future

Nigro, L. G. 1984, *Decision making in the public sector* M. Dekker

OMB 1996, 'Economic Analysis of Federal Regulation Under Executive Order 12866' Office of Management and Budget: Executive Office of the President, Washington, D.C.

Openshaw, S. and Openshaw, C. 1997, *Artificial intelligence in geography* Wiley

Paez, D., Bishop, I. D. and Williamson, I. P. 2003 *Spatial and Temporal Representation Of Environmental Policy Outcomes Using Geocomputation: A Case Study In Victoria Australia.* In ESRI International users conference, San Diego, USA.

Pereira, A. and Quintana, S. 2002 From Technocratic to Participatory Decision Support Systems: Responding to the New Governance Initiatives. *Journal of Geographic Information and Decision Analysis* Vol. 6**,** no. No.2 pp. 95-107.

Posner, E. 2001 Controlling Agencies with Cost-Benefit Analysis: A Positive political Theory Perspective. *Chicago, John M. Olin Law & Economics* Working Paper No.119.

Quintana, S., Funtowicz, S. and Pereira, A. 2002 *GOUVERNe: New trends in decision support for groundwater governance issues.* In Policies and tools for the sustainable water management in the EU, Venecia, Italia.

SKM 2002, 'Water Savings in Bulk Water Systems of Northern Victoria' Goulburn-Murray Water, Melbourne, p. 182.

Stewart, J. M. 1993 Future-State Visioning - a Powerful Leadership Process. *Long Range Planning* 26**,** no. 6 89-98.

Yager, R. R. and Zadeh, L. A. 1992, *An Introduction to fuzzy logic applications in intelligent systems* Kluwer Academic