

SPATIAL AND TEMPORAL REPRESENTATION OF ENVIRONMENTAL POLICY OUTCOMES USING GEO-COMPUTATION: A CASE STUDY IN VICTORIA, AUSTRALIA

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Abstract

For more than 30 years, cost-benefit analysis (CBA) has been used in many countries as an important tool for evaluating public policies. In most cases CBA uses Kaldor-Hicks theory, which assumes that all the entities in the analysis should be considered equal when distributing benefits and costs. However, for environmental policy evaluations, and especially for cases where a policy is directly affecting a community or ecosystem with a high degree of vulnerability, the Kaldor-Hicks theory may not be in concordance with principals of equity and sustainability. In order to incorporate these two concepts in the Cost-Benefit Analysis, a new approach to presentation of environmental indicators for decision-making is proposed. The use of spatio-temporal environmental and social indicators provides the decision-maker with a broader picture of positive and negative impacts of the policy by considering entities in the analysis in a differential form, according to their location in the space-time. A geo-computational (GC) system, which incorporates a space-time model and a geographic information system (GIS), was created and designed to generate new representations of environmental policy outcomes. The system, which could be considered as a decision support system, has been designed to promote discussion in the decision process rather than as a technocratic tool. The indicators and computer-based system have been tested in a water resources case study with long-term impacts over a large area of south-eastern Australia.

1. Introduction

Environmental policies now receive special attention from decisions makers since their decisions may affect a large number of people, regions and resources. Moreover, concepts such as sustainability surround their actions and, therefore, special attention is paid to future benefits and costs that may result if a policy is implemented.

In most cases, the decision not only consists on choosing whether to implement the policy or not. It might also entail analysing scenarios that involve consideration of different projects or actions. If we consider a case where a city wants to implement a policy for atmospheric contamination, the governors may choose between restricting the use of private cars, constructing a new highway or just doing nothing. Each of these three options, if implemented, could produce different costs and benefits for inhabitants, this obligates authorities to use a responsible and reliable method in order to estimate the effects of the various policy alternatives.

Further, estimations of effects must allow comparisons between options, so the alternative most frequently chosen is the one that maximises the net benefits¹ for society. Cost-benefit analysis (CBA) is an important tool for policy evaluation, capable of evaluating each option separately. This method, created more than 30 years ago, generates indicators that estimate in a monetary form, the net present benefits of each of the policy alternatives.

CBA assumes that all the entities (affected people, regions or ecosystems) in the analysis are equal and, therefore, losses that occur to some in the analysis are compensated with gains in others, in such way that the net result for the entire society is positive. This method has been tested in many situations and regions around the world. It is a current option for decision-makers and is encouraged for environmental policies in some countries (OMB, 1981, OMB, 1996).

Cost-benefit analysis is highly polemical in some situations, however, especially where concepts such as sustainability and equity do not admit the assumption that all the entities or regions in the analysis are equal. If we consider a situation where the survival of a fragile ecosystem is compromised, it might not be justifiable to accept an option that affects this ecological unit, although it compensates the society by giving benefits to other regions or inhabitants. A basic cost-benefit analysis cannot detect this and further studies are essential.

One alternative proposed to solve this problem is to generate additional indicators for each of the entities requiring special consideration. Although this procedure might reassure that sustainability is not compromised, it could be a time-consuming option and might not be easily applicable in a practical situation.

Therefore, the present paper proposes a computer-based system in order to support CBA in cases where spatial representation of beneficiaries is important and where some entities in the analysis require additional considerations. It is proposed to implement the System after the results of the CBA are achieved and it is not intended to replace the economic analysis, rather than to complement it with spatial results and provide an environment that facilitates open discussion.

¹ Net benefits mean the benefits the policy produced minus its costs.

The computer-based system, which has some features that permit us to categorize it as a decision support system (DSS), allows the visualization of the spatial disaggregation and also permits the creation of new indicators for decision-making using additional spatial data available for the region, such as land cover, soil type and population density. In general, the system gives the possibility for the user to gain a better understanding of possible future scenarios by, for example, showing the number of people who might suffer negative impacts if an alternative is implemented. Users develop all the different analyses and parameters in an interactive way with the system.

In order to design the different characteristics of the system, a case study methodology was applied in the state of Victoria, Australia. This methodology allows identification of practical challenges and necessary features in the system for an accessible operation by users of different backgrounds and IT levels. Preliminary results from the case study are also presented in this paper.

2. Cost-benefit analysis and its limitations when evaluating environmental policy.

A normal practice in the art of governing is to generate policies that are believed to be beneficial for the society. Different alternatives by which to achieve the goal of the policies are then developed. Subsequently, these alternatives are evaluated using in most cases economic methods, such as CBA. In this process, governors pay special attention to selecting the policies that they want to implement, but their main concern is the selection of the best policy from the available alternatives. This section will explain the types of policies considered in the present research and a description of a popular method used to select alternatives and cost-benefit analysis. Afterwards, an explanation of the advantages and limitations of CBA will be presented. These limitations justify the development of the DSS presented in this paper.

A broad variety of definitions exist for the term policy. This is mainly because policy refers to what should be done to deal with economic, technological, social, political, international and legal problems at the societal level (Nagel, 2002). For the purpose of this paper, the term policy has been narrowed in order to cover only those decisions of governments that had or have spatial effects (positive and negative) in the alternatives. For example a future policy of a government, included in this definition, could be the reduction of atmospheric contamination in a city. This policy has effects with a spatial component such as the fact that the suburbs in the city are affected differently. However, the decision of a central bank to devalue a currency is also a policy, but it is not included under the present research due to the fact that its spatial effects are not clear.

After a government has developed a policy, the next step is to generate the different alternatives available by which to achieve the goals. In most cases, these alternatives are projects that modify or construct public infrastructure. However, it is important to denote that there are policies where one or more alternatives are not requiring the development of a project. One example of this situation could be a policy of a city mayor with the main objective of controlling the density in some urban areas. One of the alternatives by which to achieve this policy could be the creation of a law that

restricts the height of new buildings. In this case, although this alternative is an option for the policy and has spatial effects, it is not a project that requires the modification of infrastructure.

Having identified the alternatives, the next step is to evaluate them. One alternative is Cost- Benefit Analysis. It is possible to find numerous books and articles with complete definitions of the theory and practice issues in CBA (For example Boardman, 2001, Dorfman, 1997, Fuguitt and Wilcox, 1999). In order to conceptualise the research problem and the application of the system to solve some deficiencies of CBA, the following lines described CBA in four steps in a similar way to that suggested by 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). For example, if we consider a transport project, where the main objective of the policy is to generate better travel time for the population, the baseline will be a scenario where no new project or action is implemented and therefore travel times maintain the current tendency.

The next step in the CBA evaluation is to identify the different alternatives for the policy. Taking the same case, the alternatives for the transport policy could be the construction of a new massive transport system or modifications in the current infrastructure. After identifying the possible alternatives, it is necessary to describe them in a technical and economical way. This would include, in most cases, an economic, environmental and social evaluation of the costs and benefits of each alternative.

With a complete picture of the alternatives for the policy, the third step is to identify the differences during time between the policy scenarios the baseline scenario. This means, to identify the benefits and costs of the policy options. Returning to the transport case, the benefits will be the difference in travel times, a reduction in contamination, better mobility, etc. between the policy alternatives and the baseline scenario where nothing is done.

The fourth and final step is to assign to those benefits and costs a dollar value. Some benefits and costs may contain a monetary value (like the construction cost of an infrastructure or the incomes due to a toll). However, some costs and benefits for the society may not be a monetary income or cost and, therefore, it is necessary to find a way to monetise them.

In the transport policy example, a reduction in travel times is considered a non-monetary benefit. Non-monetary costs could be the environmental construction impacts of the new infrastructure or increased sound contamination. These are two effects of the policy that require monetisation.

Having all the effects of the policy in a dollar form (monetised), the final step is to calculate the overall net benefits from different alternatives. 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 analyses are developed such as sensitivity analysis to determine how robust the results in the

model are, as well as qualitative information on non-monetised benefits and costs (Farrow and Toman, 1999).

The main outcomes of a CBA for decision-making are two indicators, the Net Present Value (NPV) and the Internal Rate of Return (IRR). These indicators are numbers and percentages that represent the net benefits that the community will receive if the project is implemented. The generation of NPV and IRR is a complex procedure applied in the last step of a CBA². These indicators present a clear picture of the amount (or monetary value) of the benefits of a Policy for the society. This amount is calculated for a fixed period of time, which in most cases is 20 years.

However, the indicators produced in a CBA do not show by themselves who is going to be affected and where these positive or negative impacts may occur. This is a very important issue in CBA for governments. The USA Executive Order 12866 (OMB, 1981) establishes that:

...the economic analysis should be careful to describe distributional effects without judging their fairness. These descriptions should be broad, focusing on large groups with small effects per capita as well as on small groups experiencing large effects per capita.

This presidential document requires economists not only to present an evaluation of the amount of benefits and costs, but also spatial references to these effects. Despite the high interest in the decision-makers of knowing more about the spatial component, in current practices this is a highly complex process, which requires considerable effort (Morgenstern, 1997). This issue constitutes a basis for developing the DSS. It is expected that its application in the case study will contribute to efforts to generate spatially explicit policy effects.

Another issue in CBA analysis is its credibility. Considering the complexity a cost-benefit analysis, Farrow and Toman (1999) indicate the difficulty in 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 rigorous of these estimations of future scenarios and the valuation of benefits and costs (Nigro, 1984). Therefore the monetisation of benefits is a controversial aspect of cost-benefit analysis.

We believe that society might be more accepting of CBA monetisation if the results are in a spatial form, making clearer for non-economists the spatial effects of each alternative. Moreover, the application of the suggested computer-based system could

² Complete explanations of the generation of IRR and NPV can be found in Nas, T. F. (1996), *Cost-benefit analysis : theory and application*, Sage Publications, Thousand Oaks, Calif, Sassone, P. G. and Schaffer, W. A. (1978), *Cost-benefit analysis : a handbook*, Academic Press, New York, Lesourne, J. (1975), *Cost-benefit analysis and economic theory*, North-Holland Pub. Co. ; American Elsevier, Amsterdam New York.

focus the attention, of those involved in the decision-making process, more on the results and effects of the options than on the economic processes behind CBA³.

There is another polemic aspect, however, when CBA is used to assess environmental and social policies. CBAs assume that all the entities affected by a policy are homogeneous. Nicholas Kaldor and J.R.Hicks simultaneously developed the current theory behind a CBA⁴. William A. Kelso describes this in Decision Making in the Public Sector⁵:

...a change in the state of an economy was desirable if those who gained by the change would in principle compensate those who lost such that no one was made worse off.

A consequence of applying this theory is that the vast majority of CBA begin and end by adding up equally the costs and benefits “to whomsoever they accrue” (Farrow, 1998).

Many authors (Buss and Yancer, 1999, Farrow, 1998, Farrow and Toman, 1999) denote this aspect of considering everyone equal as a problem because it affects public policies when they concern equity⁶ and sustainability.

Numerous proposals to solve this problem have been presented. Farrow (1998) considers it fundamental for environmental equity and sustainability to make an additional analysis in a CBA for vulnerable sub-groups of the population.

Farrow’s approach involves application of additional tests in the CBA by which to determine the equity and sustainability of the policy for identified groups either receiving net benefits or compensated for losses. However, the development of these tests, in a practical case, might necessitate a spatial disaggregation of effects in a CBA, information that is not always available and its generation presents an important challenge (Morgenstern, 1997)

The computer-based system proposed in the present paper facilitates the application of these tests and offers alternatives to create new spatial economic indicators that consider sustainability and equity.

³ This situation is considered to be especially valid for situations where the technical knowledge used for monetisation is highly complex, making difficult for the decision-makers and the community to understand it.

⁴ For description complete description of these theory see Hausman, D. M. and McPherson, M. S. (1996), *Economic analysis and moral philosophy*, Cambridge University Press, Cambridge [England] ; New York, NY.

⁵ Nigro, L. G. (1984). Decision making in the public sector. New York, M. Dekker. Page 10

⁶ The term *equity* is used not only referred to monetary wealth but also environmental and social.

In brief, we found three focal problems directly relate to the lack of spatial reference in results from a CBA. These issues are the necessity of knowing who will be impacted if the alternative is implemented, the credibility of the analysis because of lack of clarity in the assumptions made when monetising and the basic principal behind CBA which hinders the consideration of entities in a differential form. In the next section a computer-based system is presented, developed to approach these issues by creating a decision process that facilitates discussion and interaction between decision-makers.

We consider the application of the system will open to discussion the results from CBA by providing additional representations of the effects. This is judged to be an advantage for facilitating the decision process because more people (with different backgrounds and economic levels) could better understand the economic analysis and, therefore, participate actively in the discussion of alternatives.

3. Computer-based system

3.1 Characterization of the system

As expressed previously, the main objective of the system is to represent in a temporal and spatial form the results of cost-benefit analysis by which to clarify the general picture of the effects. The initial intention in its design was creating a Planning Support System (PSS). However, the definition of a PSS is a system which links a variety of computer-based software supporting decisions at different stages of the planning process (Batty and Densham, 1996). The system being developed here could not be characterized under this title. This is principally because the system will not be an interactive tool present throughout the process. Instead, it runs after the results from a CBA are achieved.

Alternatively, the System could be categorized as an expert system (called also knowledge-based systems) especially because the module that generates new spatial indicators for decision-making contains one of the principal characteristics of these systems, being to replicate certain aspects of expertise (Jun, 2000). However, it is not truly an expert system because the validity of the results that could be produced depends on the knowledge of the users. This means, System users must fully understand the economic and technical concepts behind in order to generate coherent results.

Probably because the system is intended to cooperate with the decision maker, we consider it a decision support system (DSS) with the focus on help in the discussion process of alternatives rather than being a highly technocratic system that deploys mainly technical information.

The System could be well be defined as a DSS if the concept developed by Pereira and Quintana (2002) is adopted, which describes DSS as a context and platform for helping all those involved in decision making processes to access the policy information for a useful debate to take place. An example of DSS with the same approach is GOUVERNe, created for groundwater governance issues (Quintana et al., 2002).

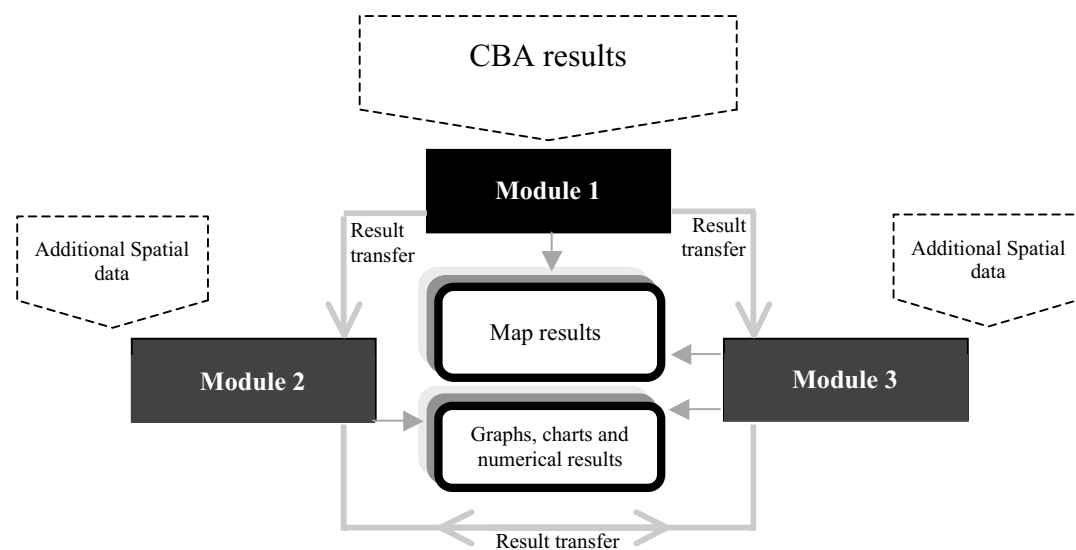
Consequently, the Computer-based system created is a DSS, which incorporates some elements that could be useful in a planning process and, in some modules, operates as an expert system by simplifying some of procedures for users.

3.2 Modules and its operation.

The main objective of the system is to generate map representations of the effects of policy alternatives and also to create additional indicators using the results from economic analysis and supplementary datasets that might not have been used during the economic evaluation process.

The system is composed of 3 modules: Module 1, which focuses on disaggregation of results from the CBA, Module 2 created for incorporating and processing of additional spatial data available for the project and finally Module 3, which is the segment of the System dedicated to the generation of customized spatial indicators for decision making. Although each module operates separately, there is a frequent exchange of information between them and their results are mutually dependent. Figure 1 shows a general scheme of the System.

Figure 1: General design and information transfer in the system



In this figure the only apparent different between module 2 and module 3 is that 3 gives maps and graphs but 2 only gives graphs. Give the modules names or somehow make their different functions clear.

The operation of the System starts by entering the results from the CBA to the first module. This module disaggregates in a spatial and temporal form the results from the CBA. With these map results, system users can decide whether to generate additional maps using any kind of spatial information available in module 2 or develop, in module 3, additional economic and environmental indicators according to parameters

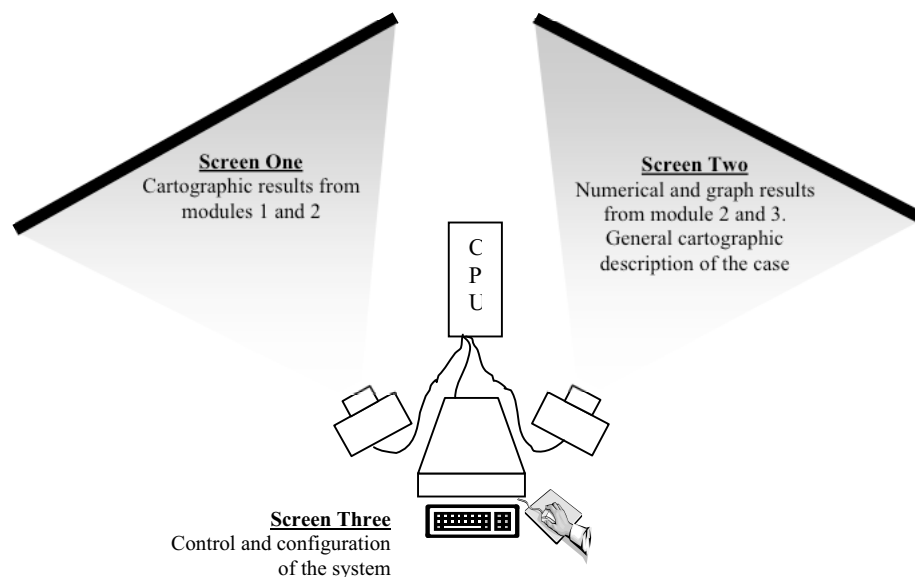
given. Module 3 also allows generation of indicators using results from module 2 or a combination of results from module 1 and 2.

Because an important objective of the System is to provide decision makers with useful information for discussion, the design of the System took into consideration the necessity of transmitting all the functionalities and results in a clear, flexible and dynamic way. Additionally, the incorporation of geographic information systems (GIS) capabilities, from commercial application, was seen as an important feature for multiple spatial calculations, needed to generate the desired results.

In consequence, and considering other experience in similar systems such as STEM (Morris et al., 1999) where rapid development of user-friendly interfaces was possible, the System was developed using a combination of ArcGIS, Visual Basic and Windows API.

Additionally to the software characteristics, the DSS was installed in a PC desktop computer with a Matrox Pahelia AGP graphic card. This card can divide the image from the computer in three screens, allowing the visualization of each of the parts in a separate monitor or projector. The following diagram (figure 2) shows the physical and hardware configuration proposed for the System.

Figure 2: Physical and Hardware configuration proposed for the System



This configuration of the System could be installed in a conference or meeting room permitting the interaction between many people in the decision process and the program. However, it is important to denote that the current development of the System only permits one-person manipulation. This limitation is discussed in the conclusions of this paper as well as some solutions to address this issue.

To provide a better picture of computer-based system developed, the next section presents a detailed description of each of the modules.

3.2.1 Module 1 disaggregation of results from the CBA

As explained, in some cases it could be useful to know not only the amount of benefits, but also the location of those benefits in the space. Module 1 generates representations of effects for each of the policy options separately. If desired, further analyses between alternatives can be developed, but these should be completed in module 2.

The current developed of module 1 only permits representations of effects using distance relations, which disaggregate the effects in the space according to the distance of each region or entity in the analysis to spatial features called “Source of effect”. In other words, for this method the effect (positive or negative) received by each entity in the analysis (community, ecosystem, region, locality, etc) depends on its distance to the features causing the impact.

For instance, if the effect analysed is water contamination in a lake, the impact of the surrounding inhabitants will be according to their distance to the lake contaminated. This spatial distribution could be done using a direct relation between distance and impact (more distance, more impact) or inverse relation (more distance, less effect). To define this and the proportion of the effects for each element or entity in space, the user can choose between having a polynomial equation (with a maximum degree of 3) or using a raster layer as definer.

The result of Module 1 is a raster layer where the value of each cell is the effect received according to a scale that the user defines.

The fact that currently only one method is available in the DSS developed could be considered as a limitation because not all the effects might be correctly disaggregated using the concept of distance to the “source of effect”. This limitation is highly important especially if it is considered that all the possible results in the different modules depend on the disaggregation achieved in module 1. It is a priority for future developments of the System to research additional alternatives for spatial representation of effects.

The methodology that will be described next applies only for generating results using distance relations. The addition in the future of additional tools may cause a change in the procedure for representing effects in module 1.

Before starting operating module 1, it is requisite to analyse from the CBA the principal benefits and costs considered in the analysis. This selection of effects would be the basis for future analysis and the validity of results would depend widely in the degree of importance of the effects selected. If significant impacts (positive or negative) are absent or not correctly represented, results may perhaps not signify the real situation for the alternative, decreasing the validity of the analysis. Therefore, it is considered significant to perform this selection of representative impacts (benefits and costs) in accordance with the results from the CBA and giving participation to all the entities involved in the analysis, so those effects that are not included in the analysis are truly considered as irrelevant by the users of the System.

There is no limitation in the maximum amount of effects that could be analysed by module 1. However, the time in processing the different analysis in the computer program is directly related to the number of effects that have been considered.

Processing times in Module 1 also depend in the number of spatial elements in the data used.

With the inventory of effects (positives and negatives), the initial operation in module 1 is to link each of the effects with a spatial layer⁷. This linkage should be done according to the characteristics of the effect to the data available for the study area. From this layer linked, the source of effect will be selected.

For example, in our case study there is a significant effect (positive in some areas and negative in others) directly related to water quality in the Bulk Water System. It was found by the economic analysis that depending on the options, some parts of the water system would have in the future better water quality while others may have a worst condition than the present. In order to produce spatial disaggregation for this effect, the layer linked was a linear feature that represents the Bulk Water System because this layer permitted us to join water quality data modelled for each segment to the surrounding productive areas. Each of the lines, for which we had data that shows water quality change, was defined as a “source of effect”.

With each effect linked to a spatial layer, the next step is to define the characteristics of the representations that will be generated. To perform this, the user selects if the relation between distance and effect is direct or indirect and if the distribution of effects will be according to a polynomial equation or using a raster layer as definer. Additionally, the user specifies the range of distance that will be considered in the disaggregation by defining the minimal distance and maximum distance to be used.

With these parameters, the System generates a raster layer in which the value of each cell represents the amount of impact that is received from the different sources of effect.

Practically, module 1 has a function that controls the different effects that are modelled. In this function, it can be add new effects to the analysis by linking it to a new data or remove those effects that are not required.

For each of the raster results generated, there is a user interface that shows users the parameters used. Additionally, a small map image shows the original vector layer used to generate the result.

System users can generate combined results for some or all of the effects. To create this type of results, another function in the System allows the user to weight the results for the individual effects and add them all, action that generates a raster map with a consolidated representation of effects in the System.

With this result, the net present value (NPV) can be spatially disaggregated by dividing the total amount of benefit for the option according to the amount of effect (positive and negative) that each zone is receiving. This result, that is a normalization of the raster consolidated result according to the results from the economic analysis, is the principal outcome of module 1.

⁷ Spatial layer refers to a file or collection of files for data in any of the vector forms (point, line or Polygons)

3.2.2 Module 2: incorporating and processing of additional spatial data available

One of the principal objectives of the System is to incorporate spatial data available for the study area, which might not have been used in the economic analysis. These data could be land use, land cover, government boundaries, demographic, etc. and its incorporation to the policy analysis (combined with results from module 1) could provide a better picture of direct and indirect effects that might be occurring in some sectors of the economy, or in some aspect of the environment, represented by the new data added.

Probably a typical example, which is considered as fundamental in many analyses, is to incorporate demographic data to the results, which might not be employed in the CBA. Using module 2, it is possible to generate a map that shows the raster results from module 1 and a map of density of population at the same time. To perform this, module 2 converts the results from module 1 into a vector file according to user parameters. Afterwards, this vector layer is clipped by the demographic data. The system permits only in a direct form to show the two variables (the amount of effect and population) using colour thematic map.

If system users desire to generate other type of representations for two variables or more in a single map, a more advance GIS knowledge is required to apply the spatial operation in ArcGIS⁸.

Module 3: customize spatial indicators for decision-making

Module 3 is similar to module 2 in terms of providing access to new data for analysis. However, the main different between modules 2 and 3 is that the results in module 3 are not in a map form. Module 3 generates graphs and charts that show the different relations between effects of the option and the other data. Additionally, it is possible to reaggregate outcomes as indicators for decision-making.

For example, if β is an indicator (single number) represented by the formula:

$$\beta = \sum_{i=1}^n (Income_i * LA_i * P_i)$$

Where:

Income_i is the average income for the zone i

LA_i is the level of effect for zone i according to the results in module 1

P_i is the population for zone i

And if the sum in β is calculated for all the n zones⁹ in the analysis, the result for β will be an indicator that represents not only the net total benefit of the option (which in the CBA is given by the NPV) but also it considers the income and number of people in the analysis.

⁸ As was mention before, ArcGIS is the commercial GIS software used as a GIS platform for the development of the DSS system

⁹ The term zone in all the formulas represents the spatial division available for the analysis. Practically this could be local government boundaries, electoral boundaries, census collection districts, etc.

Similar indicators to _ are generated in module 3 by providing the variables that should be included in the indicator and the mathematical relation between them. The system uses the attribute table of the layer produced in module 2 and calculates the indicator. However, before creating this flexibility, it is necessary to perform some manipulation to the results from module 2, involving some advance knowledge of GIS.

The main advantage of generating new indicators, such as _ is to obtain new figures that described the policy option, apart for the standard NPV and IRR produced by the CBA. In the same way as these economic indicators, the new spatial indicators could be compared between options, allowing new elements for discussion in the decision process.

It is important to clarify that the DSS was developed specifically for Lake Mokoan (see below), with the criteria used in each of the modules according with the aims and necessities for this case study. More flexibility may be incorporate to the present system, especially in terms of adding new analysis and result presentation. However, every modification in the data structure and in the analysis capabilities required extends development of programming code in Visual Basic and ArcGIS.

4. Case study (Lake Mokoan) and preliminary results with the System

A case study methodology has been proposed in order to develop the System. Therefore, the different developments and features of the System were developed according to the challenges and difficulties presented by Lake Mokoan. This section presents a description of the situation in Lake Mokoan and the preliminary results achieved with the System. At the current time of writing this document the Lake Mokoan project has not been fully finalized and new economic results from CBA are expected.

4.1 Lake Mokoan case study

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 water saving in the north part of the system, the need of detailed analyses of different alternatives was noticed because any of them would impact positively some regions and negatively others. In consequence, the government decided to contract a consultant company to analyse the different alternative for saving water in the state of Victoria. This made it an ideal case study.

The consulting firm Sinclair knight Merz (SKM) was contracted and conducted preliminary studies for evaluating alternative water saving policies¹⁰. In these preliminary studies, main options for saving water were determined. Changes to Lake

¹⁰ Water Savings in the Bulk Water System, Preliminary study for the Department of Natural resources and Environment, march 2002.

Mokoan produced the largest net water saving (SKM, 2002). Among others, returning Lake Mokoan back to a swamp and reducing its capacity were identified as key options to achieve water saving in the system.

Consequently, the Victorian Government has focused its water saving efforts on Lake Mokoan. Recently, it has started a study for the future of Lake Mokoan. The results that we present in this paper correspond to the results achieved by SKM during the preliminary studies. However, the System is in process of evolution and will be capable of analysing the new economic results and CBA that will be produced in the near future.

Lake Mokoan is an artificial lake located in North Victoria, close to the town of Benalla. The construction of a dam wall and flooding swamps formed it. The water is supplied from the Broken River using a channel and, when required in other regions, some volumes of water are supplied back to the system.

In the past two decades, the storage has not been used as much as it would be desired due to water quality problems (SKM, 2002). The main problem is blue-green algae. Also, the lake's shallowness and large surface cause high rates of evaporation.

Using hydrologic computer systems, SKM modelled different alternatives to save water by changing Lake Mokoan. Among others, one of the options proposed is to eliminate the dam wall and return Lake Mokoan back to a swamp. This option achieved the maximum amount of savings (41.832 ML per year)

In the preliminary studies, SKM determined the shortfalls¹¹ of the system if this option is implemented. Additionally, three financial indicators involving the cost of the project and the savings were developed.

Furthermore, these preliminary studies analysed many options involving different alternatives to cover the shortfall that could be caused if Lake Mokoan is removed from the system. For all these options, some hydrological and financial indicators were calculated in order to compare the different scenarios. **Table 1** shows the results for three alternatives.

Table 1 Extract of results from preliminary studies

Run	Description	Average Reduction in evap. (ML/yr)	Average Increase in shortfall over base case (ML/yr)	Net Savings (ML/yr)	Saving plus offset Cost (Present Value, Mill)
Wi10	Winston's swamp	41.841	1,971	41,832	\$6,11
Wi13	Winston's Swamp, Tungamah Pipelining from Broken, Nillahcootie raised 1.0 m	41.245	980	45,719	\$8,03
Ptl8	Partition Lake Mokoan	26.644	1,623	23,232	\$13,8

Source: SKM study -2002

¹¹ According to the Bulk Water system preliminary studies Shortfall is the demand that cannot be supplied at the point of delivery.

Although this preliminary results are not from a CBA, they were considered as an important basis to initiate the development of the systems, so in the near future the DSS could process the results from the CBA.

Figure 3 to 5 contains initial results, developed using module 1 of the computer-based system, for option W13, which involved the return of Lake Mokoan back to a swamp and the raising of Lake Nillahcootie to reduce water shortfalls in the system.

Weighting the different environmental parameters (such as water quality, flora and fauna and flow quantity) created these results. The basic method was linear distance from the source of environmental detriment or benefit using raster GIS.

Probably an important advantage of the System is the incorporation of data available for the project not considered during the economic analysis. In consequence, Figure 7 shows a map of the different types of agriculture and the degree of effect that may occur if option W10 is implemented. This result was produced using Module 2.

Further analyses can be conducted with the results presented. For example, one alternative could be the incorporation of political information such as electoral boundaries, or demographics such as the census collection districts. As an alternative for this type of analysis, figure 8 shows a graph of the areas affected in each Local Government Areas (LGA) using the results presented in figure 7.

