

# **DISCUSS: An alternative for taking decisions with an incomplete SDI**

## **ABSTRACT**

An ideal situation for a country or region will be to have a spatial data infrastructure (SDI) containing the datasets and models necessary to support all the planning and decision processes. Often, especially in developing countries, this is not the case. Can governments take good and valid decisions in cases where the available SDI is not capable of having all the datasets or models required for the decision? In order to approach this question we have developed a decision support system called DISCUSS (decision information system for community understanding of spatial scenarios). DISCUSS is a customised application under ArcMap and uses a fuzzy logic methodology to incorporate the soft information from the experts and the community into the decision process. The main objective of DISCUSS is to reduce uncertainty in the spatial distribution of decision impacts and at the same time support public participation. The System and the maps that it produces are being tested in a case study with long-term consequences for a large area of south-eastern Australia.

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## **Introduction**

The main objective behind the generation of a Spatial Data Infrastructure (SDI) is supporting decision-making. SDI is the foundation of data to be used in making better and more efficient decisions in the public and private sectors (Feeney, 2003).

An ideal situation is to have the entire data, models and technologies required for the different decision process in a database that is up-to-date and accessible to everyone. Many countries have been working over the last decade in achieving a real infrastructure capable of supporting the decision process. These efforts are occurring not only in the developed world, but also in many less developed economies. It is a reality that today many nations around the world identify SDIs as a key aspect to better decision-making and, therefore, sustainable development for the people.

However in some conditions, not all the required information for decision-making exists in the SDI. Can governments make useful and valid decisions in cases where the available SDI is not capable of having all the datasets or models required for the decision processes? In order to approach this question we propose to complement the available SDI with community knowledge (also know as soft information from the community). For this purpose of adding the community knowledge in decision processes we have developed a decision support system called DISCUSS (decision information systems for community understanding of spatial scenarios).

In the first part of this paper we explore the importance of the SDI in supporting decision process and in fostering the sustainable development of countries. Afterward, we explore the limitations that governments encounter when SDIs do not contain all the required data. Subsequently we present our justification for using community knowledge and the decision support system DISCUSS. Finally a discussion about the results found in the case study and opportunities for future research are presented.

## **SDI and decision-making**

The importance of developing an SDI is something recognized in most places of the world. Multinational initiatives such as the Global Spatial Data Infrastructure (GSDI) conferences, United Nations Regional Cartographic Conferences and the meeting of the UN-sponsored Permanent Committee on GIS Infrastructure for Asia and the Pacific (PCGIAP) demonstrate the increasing role that the construction of an SDI plays in the agenda of nations (Williamson, 2003) .

Defining SDI is not an easy task. Williamson (2003) explains how the concept of SDI has been modified through the years to incorporate the needs and

technological developments in the different jurisdictions and also the political and social environments. Probably a generic definition which could be applied in most of the cases is presented by GSDI in its cookbook (GSDI, 2004). They define SDI as the relevant supportive collection of technologies, policies and institutional arrangements necessary to facilitate access to spatial information. Furthermore, they describe the SDIs as the foundations for data discovery, evaluation and applications for users in the different levels of the public and private sectors.

It is possible to visualize many reasons for developing an infrastructure capable of providing ready access to spatial data. One of the most important motivations is the efficiency of sharing information in order to reduce costs and improve services. For example, the road network dataset in a city is commonly used by many utility companies for planning and delivering their services. This map could be more efficiently developed if it is included in an SDI where all the utility companies have access to it. Under the SDI they can share the cost of updating and improving the map and at the same time a common format and characteristics could be set for the dataset in such way that everyone participating in the SDI could use it in their own decision processes.

Chapter 40 of the Multinational declaration Agenda 21 (UN, 2003) is especially dedicated to highlight the importance of information in decision-making. Moreover, in this section of the declaration a special interest is placed in two plans for improving decision-making: a) bridging the data gap and b) improving information availability. If we consider the important role that spatial information plays in decisions where environmental and social aspects are imperative, these two plans proposed for the future are in direct relation with the formation of an SDI.

The Commission for Sustainable Development (CSD) of the United Nations argues that reliable access to information is essential for knowledge-based decision-making. They also stress the importance of having the information at the correct time and costs by which to achieve better decisions (CSD, 2000). These translate to having a better information infrastructure to support the decision process in the academic, private and public sectors of the society. This infrastructure, capable of facilitating the share of information, is the SDI.

This awareness around the world about the importance of SDI allows us to visualize a future where sharing of information at all levels in our societies is facilitated. Future development of the SDI will depend on the technological developments underpinning the SDI (Williamson, 2003) and on the continuation of interest and support from governments and public sector in constructing SDIs at all levels of the society. However, the support of government and the private sector in developing the technologies required for the SDI depends on their interest in SDI. Consequently, the challenge is to maintain the interest so

research on the technologies and implementation activities can be achieved. With new technologies, future SDI initiatives could be more achievable for developed and developing countries.

Although wide international interest is shown in developing an SDI, the vision for many nations, especially developing countries, is that the SDI will take some time to be formed before it can support decision-making in all fields. Despite this, the reality is that nations need to continue taking decisions regardless of the level of development of the SDI. Can countries with partially developed SDIs use them for improving their decisions although all the information is not present? In the next section we analyse some difficulties that nations confront in developing SDIs and it is proposed to include community knowledge as a complement to the existing SDI in cases where the available information cannot cover all the aspects of an issue. We consider that this inclusion allows countries to use the existing SDI, while at the same time maintaining their interest in full SDI development.

### **Using the current SDI and community knowledge for better decision-making**

Developing an SDI is vital for the future of all nations and efforts to this end should continue. However, building an SDI is complex. This is not only because the dynamic of the SDI concept, but also because of the social, political and technological context that surround its creation and development (Williamson, 2003).

The establishment of an SDI requires the endorsement not only of current governments. It is normally a continuous effort trespassing public elections and political changes. It requires significant economic investment and cooperation between different levels of government. The public, private and academic sectors play a vital role in its achievement.

These conditions and the economic actuality of nations creates an SDI development continuum where each country is at a different point (Williamson, 2003). Currently, it is possible to find nations such as the United States of America where the national spatial data infrastructure (NSDI) initiative has been supported by presidents for a long time (OMB, 1994) and it is developed to an advanced phase. In opposite situations are countries such as Benin or Burkina Faso in the Africa continent where SDI initiatives are highly immature and have not reached any implementation stage (ECA, 2003).

For those nations where the economic constrains produce a difficult situation to generate and implement a fully operational SDI, the current support that spatial information provides to decision processes is minimal, meaning that in some cases the decisions must be taken without having the best information. This

limitation of information restricts dramatically the ability of these countries to achieve sustainable development (CSD, 2000).

Another problem for these countries is the risk that the SDI initiatives lose social and political support if tangible results are not achieved in the short term. Countries with low resources for development of an SDI might enter in a cycle where the lack of usability of the SDI reduces its use in decision processes. Low usage creates a lack of interest in developing the SDI and, therefore, the resources for its growth are constrained. This, after occurring few times, could increase the risk that the SDI initiative might not continue.

In order to help government take better decisions in situations where complete information in the SDI does not exist and at the same time motivate a practical use of the SDI regardless of its condition, we propose including community knowledge in the decision process to complement to the formal information available.

Community knowledge, or soft information from the community, is the subjective information about the alternatives proposed in a decision process. This might be gathered by using some form of public participation. Malczewski (1999) defines two types of information for decision-making. One is called *hard information* and is the information obtained by technical procedures. Examples include transport models, mathematical estimations of future conditions and economic forecast of markets. For the particular case of an SDI, hard information is all the datasets collected using scientific or technical methods. Cadastral boundaries from land surveying, vegetation mapping from remote sensing sources or a road network defined using GPS are examples of hard information in the SDI.

The other type of data for decision-making is *soft information*. This type of information comes from personal or group knowledge and cannot be linked to technical or scientific procedures. This information is subjective and relates to individual perceptions. Currently, soft information from experts (also called expert knowledge) is commonly used in decision process. For instance, soft information is used for decision-making when experts are called to weight factors in a multicriteria decision process (Malczewski, 1999).

Under this category of soft information we can include community knowledge. This information is not new to decision processes and is recognized by important multinational bodies as a key component in the environment for decision-making (UN, 2003).

Despite the longstanding awareness of the value of community participation in decision process, today it is still a challenge for decision-makers to incorporate both soft information and hard information into their analysis (Kasemir, 2003).

While hard information provided by a model might be measured using exact units (such as kilometres, litres per day, grams, etc.) soft information in will typically have a more fuzzy scale.

A common practice is to develop the decision process based on hard information and afterward expose to public participation its results by which to obtain the acceptability of the community for the technical information proposed (Paez et al., 2004). However, in the case of some poorly developed SDI the available hard spatial information is not sufficient to provide the necessary bases to support the decision-making process. This could produce some scenarios where the SDI cannot be used until it contains the core datasets necessary for most of the decisions processes.

Alternatively, if community knowledge is conceived as a source of information as legitimate as hard information, it could be used to complement the existing datasets and models in the SDI and, therefore, make possible to use the current information infrastructure regardless of its degree of development.

One example of research developed under the bases of community knowledge is a crime condition study made for the city of Wollongong, in the state of New South Wales – Australia (Doran and Lees, 2003). In this study, the fear of crime of residents in the central business district was collected and subsequently compared with hard information obtained for social disorder acts and crime events. The results of this study showed an important correlation between the fear of crime and the actual areas where crime occurred. This result demonstrated for this particular case that the soft information from the community was as valid as the hard information about crime available in the SDI for the city of Wollongong.

The City of Wollongong had for the police force the necessary spatial information to take actions about crime in their city. However, this could not be the case when an SDI is not well developed. Recently we had a personal experience that showed us a situation in where a decision was not supported because the SDI was not complete.

The capital of Colombia, Bogotá has a well developed road network dataset maintained by several institutions. This dataset, along with other spatial information were part of an SDI for the city established between governments agencies involved in the development of transport infrastructure. By the year 2001, The SDI was well maintained and updated. For the case of the road network it contained a layer with a highly accurate identification of intersections and a complete description of the characteristics of all the segments of the network.

The Planning Office of Bogotá in 2002 decided to use this dataset in an analysis of traffic accidents “hotspots”. The idea was to identify the intersections where high rates of accidents occur and based on this identification, guide the investment on future road safety features such as traffic lights and road signals.

Having a well developed road network map (hard information collected using aero-photography and land surveying), the only information required to support the investment decision was the historical location of accidents. Unfortunately, when the administration intended to geo-reference the reports of accidents for each intersection it found itself in a gigantic labour, which due to lack of resources it was not able to complete. An archive of accidents reports existed, but the number of report per year were too numerous to be digitized. In addition, the location of the accident in each report was not easy to geo-reference due to the lack of a consistent coordinate system for identifying the location. Hence, the well developed layer for the road network could not be used because other information in the SDI was not available and the decision-making process was not supported.

For this instance, an alternative for the administration could have been to use soft information from the community that uses the public and private transport-systems. A more affordable alternative could be to survey users of the transport network regarding their perception of “hotspots”. This information can afterward be validated with a reduced number of digitized accident’s reports. This soft information could subsequently be compared with the road network layer, producing results for supporting the design and distribution of safety features for the roads. Under this alternative, community knowledge could have helped Bogotá to take a better decision and at the same time allowed the use of the existed SDI. This would promote its develop to a better stage where a wider range of decisions could be supported.

In order to add soft information in some particular decision processes we have developed a decision support system called DISCUSS (decision information system for community understanding of spatial scenarios). The methodology used in DISCUSS to collect information from the community permits its transformation into a form comparable with technical data, enabling it to be used for decision-making situations.

Nonetheless, many reservations exist when adding information from the community involved in the decision. Probably the most relevant issue is the fact that community knowledge could be highly biased by private or particular interests, and therefore the decision could be directed to beneficiating some specific interests rather than the welfare of the entire community. DISCUSS addresses this problem bias in the community input by developing a validation methodology to the inputs.

In the next section we explain DISCUSS and its application in a case study with long-term impacts over a large area of south-eastern Australia.

**DISCUSS: Decision information system for community understanding of spatial scenarios.**

The decision support system DISCUSS was initially created with the primary interest on identifying the areas where agreement and disagreement between stakeholders exist. The system was mainly developed to be used in cases where cost-benefit analysis is chosen as methodology to evaluate the different alternatives. The system is flexible and permits modification to be applied in other methodologies for evaluating policies or projects.

Some significant results were obtained for a decision processed in the state of Victoria – Australia, where a future development for Lake Mokoan was under consideration (Paez et al., 2004, Paez et al., 2003). These results showed the importance of identifying the areas and effects that are causing more disagreement between stakeholders. For the decision process, the results about perceptions are highly significant for the government in developing a strategy for identifying the regions and aspects that require more attention in the discussion process of the options. On the other hand, information about disagreement is also important for the stakeholders because identification of zones with disagreement allows them to see not only where disagreement within communities exists, but also how different their positions are when compared to governmental perceptions. Figure 1 show one example of a result using DISCUSS. The dark areas represent zones where disagreement between stakeholders exists for one of the option proposed for the future of the Lake.



Figure 1: Disagreement between stakeholders about the effect of water savings under option 1 for Lake Mokoan

The information from the stakeholders was collected using three alternatives: paper back-projecting, direct drawing in the system and facilitator's drawing. The stakeholders had complete freedom in choosing their preferred alternative.

The first alternative in the system (paper back-projecting) allows the stakeholder to use markers on a white paper sheet with a back-projecting image of the system behind it (see figure 2 and 3). In this option the user was provided with a scale of colours to draw the areas which he or she considered might receive a positive or negative effect if the future option for the Lake is implemented. This perception was acquired for three future options for Lake Mokoan and also for some individual effects of these options such as changes in land values, operational costs and recreational activities.

The second alternative for inputting to the system is direct drawing in the system. In this case the stakeholder uses a simple interface in the system to draw polygons, which represents the areas receiving positive and negative impacts. The third alternative – facilitator's drawing- is similar to the previous one with the difference that the operation of the system is made by a facilitator that only interprets the desires of the stakeholder. These methods to input the disagreement were also used with the government officials.

During this analysis for Lake Mokoan the potential of DISCUSS to develop into an interface to obtain information for complementing the SDI with soft information became clear. In this particular case in the state of Victoria, we found that one effect of the future options for the lake was not clearly defined in a spatial form by technical studies. This effect - land values - was of significant importance for the stakeholders and the government. However, a spatial distribution of which regions were going to be affected in their land values was not available from the technical studies made for the cost-benefit analysis.



Figure 2: Back-projecting system used in the Lake Mokoan analysis

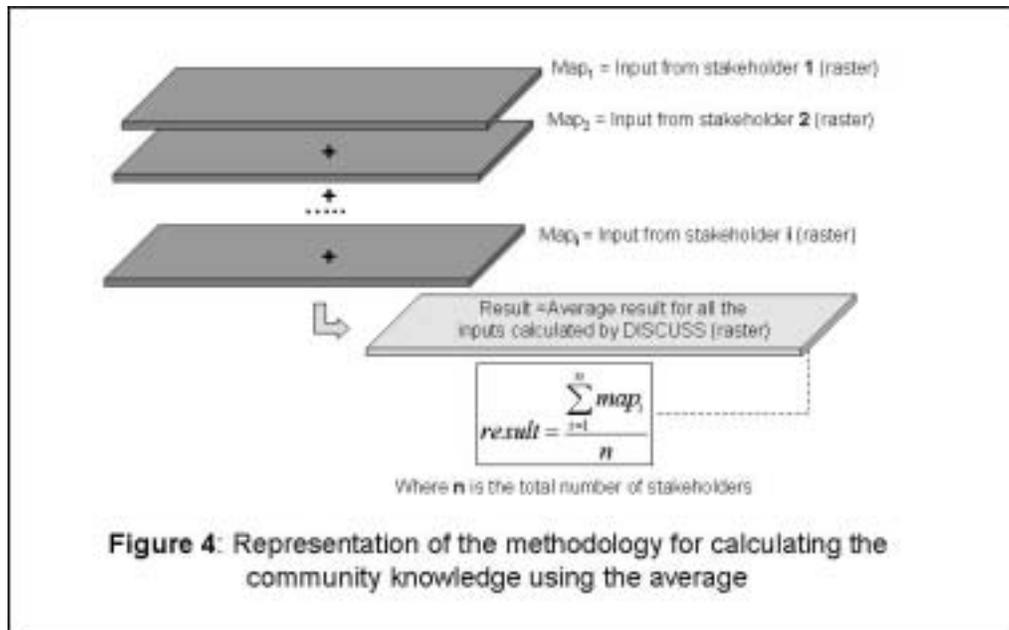


Figure 3: Back-projecting system in a Stakeholder' residence

This data about the distribution of effect in land values could be important in a situation such as Lake Mokoan for future decisions. For example, the government might decide to consider possible reductions in taxes for those stakeholders and communities where the implementation of an action in the Lake reduces the market value of the land.

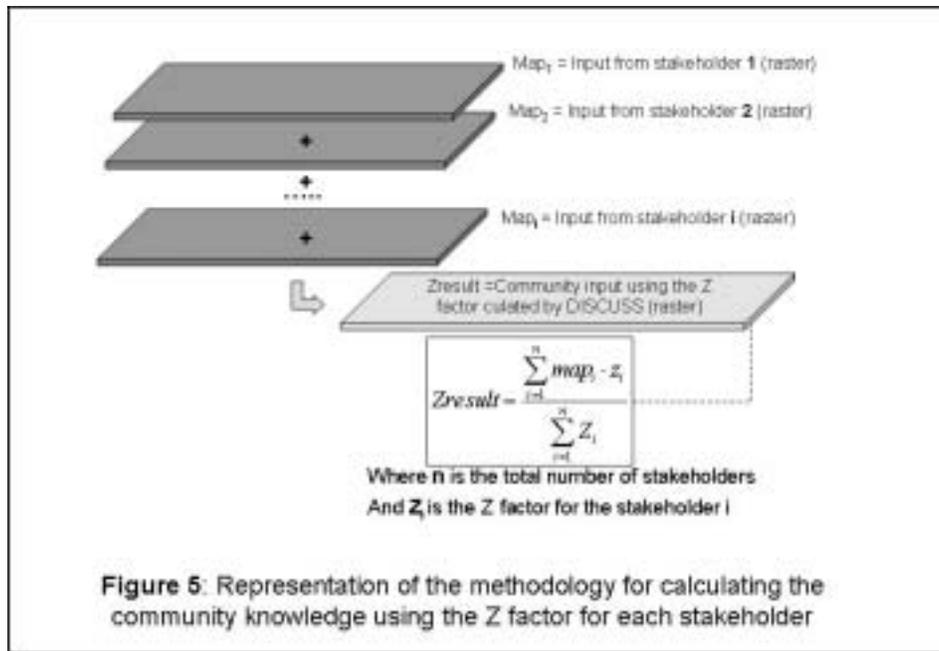
One option to generate this map, using soft information from the community, could be to add all the different perceptions for the study area and calculate,

using a raster representation of the option, the average for all the options (figure 4).

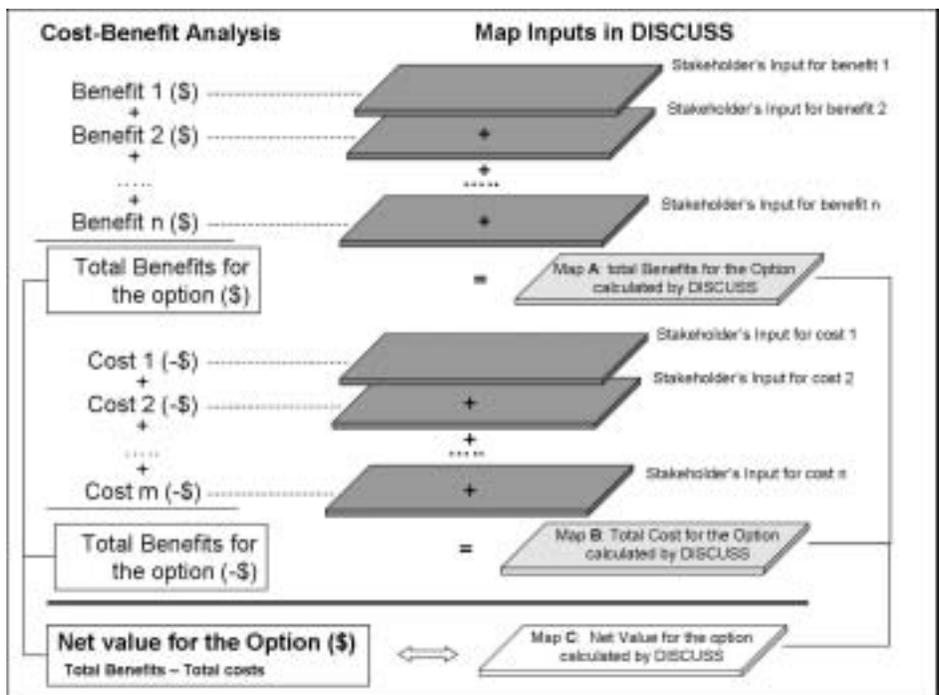


Although this option could provide a good insight of what the people perceive about future effects, it also allows room for bias toward some particular interest. For instance, some owners of a parcel in the study area might exaggerate their perception. This may promote a possible mitigation action that does not correspond to the actuality.

To reduce this effect of private interests influencing a decision, it is proposed to weight the value of each input map with an indicator that measure the independence and consistency of the input from each stakeholder. In other words, the final result map represents more those inputs which are perceived as less bias toward a particular interest. We have called this factor  $Z_i$ , where  $i$  represents and identification of each stakeholder or government official participating in the analysis (Figure 5).



The Z factor was defined considering that Lake Mokoan had a cost-benefit analysis (CBA) as basis methodology for evaluating options. In a CBA, the net value for the option is equal to the net value of subtracting the sum of all the cost from the sum of all benefits. Figure 6 shows the relation between the CBA and the maps of inputs for each stakeholder.



**Figure 6:** Comparison between cost-Benefit analysis and the input from the stakeholder

Each stakeholder inputted to the system a map of perception for each effect in the CBA. DISCUSS can then calculate Map A (see figure 6), which represents the total perception of benefits for the option analyzed. In the same way Map B is calculated tallying the costs. Map C is a representation of the net benefit for the option and is calculated by subtracting from the total Benefits (Map A) the total costs (Map B). It is important to note that maps A, B and C are calculated by DISCUSS.

In addition to these individual maps for benefits and costs, the user inputs a map of his or her perception for the entire option, which is called Map D. This means, the user has to express, considering all the possible effects, where the benefits and costs will occur if the option is implemented. The assumption is that a well informed stakeholder with no bias for a particular benefit or cost will produce an entire map for the option (map D) consistent to Map C, which is calculated by DISCUSS and depends on individual identification of effects. For this particular project, consistency is the main concept for identifying well informed stakeholders without bias towards any option.

Having these two maps, and considering that map C and D are in a raster form, a map of the difference between C and D is calculated (map E) and then the indicator T is the total sum for all the cells in map E. The assumption is that if T is small, the input was consistent and therefore a good interpretation of the future impact.

Having the indicator T, the Z Factor for each stakeholder is calculated by applying the following formula (1):

$$Z_i = 1 - \frac{\max(T)}{T_i} \quad (1)$$

Where  $Z_i$  is the factor for stakeholder  $i$ ,  $\max(T)$  is the maximum value for all the stakeholders analysed and  $T_i$  is the indicator T calculated for the particular stakeholder. This Z factor is used to calculate a total input from the stakeholders as shown in Figure 5. The result map is the community knowledge to be added into the decision process as soft information.

Using formula (1) for calculating Z, the stakeholder whose value of T was the maximum obtains a Z value of zero, meaning that its inputs will have no effect in the final result. It was discovered that eliminating the stakeholder with the maximum Z factor produces a better total result for the effect analysed by reducing the standard deviation.

## Discussion

Public participation has been identified as a key aspect for the long term success of the alternative selected during the decision process (Ball, 2002). After our experiences with Lake Mokoan and the situations in the City of Bogotá, we perceive public participation also as an important component of the infrastructure required for developing better decisions. Public participation could be seen as a source of knowledge for finding the best alternative that guarantees sustainable development.

DISCUSS provides an alternative to support decision-making in many fields. However the system requires more development to fully understand how the community experiences can be transformed under all circumstances into a valid result that can be compared with information from scientific knowledge. Moreover, we recommend developing a detailed study of the circumstances and communities involved before deciding about the incorporation of community knowledge in the decision process.

Community knowledge has its limitations. More research is needed to approach the difficulties of bias in the input and additional technologies are required to optimize the input from stakeholders. Also, the collection of the information from public interactions in large scale projects could be extremely expensive, making soft information for these situations inefficient.

The methodology for incorporating soft information into the SDI requires more research. The proposed method for weighting the validity of the stakeholders' inputs with the Z Factor was proven to be effective in the case of Lake Mokoan. For this particular case, and due to the fact that a cost-benefit analysis methodology was used, consistency determined the validity of the input from the community. The application of this methodology with the Z factor in other decision environments requires more investigation by which to corroborate if consistency represents a good indicator of the validity of the input from the community.

Furthermore, the SDI cannot be limited to geographic information from the community. Adequate arrangements are required to add information from a public participative process with no geographic references into data infrastructures. Nevertheless, the alternatives presented for soft information could contribute to the development of better decision support in cases where the SDI is not well developed. We consider that in addition to the potential enhancement of the decision, the fact that the SDI is used (although it is not well developed) could contribute to promote a wider interest and, therefore, attract more resources for developing the SDI in the future.

Williamson (2003) identifies the community as an important user of the SDI infrastructure. In the future, this community might be perceived not only as a

user of the infrastructure, but also as a source of information for decision-making in order to achieve sustainable development.

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