Lessons from an Environmental Information System Developed to Select a Radioactive Waste Disposal Site

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Abstract: Lessons are presented that have been derived from an Environmental Information System (EIS) developed to assist the potentially contentious decision-making task of selecting a suitable site for the disposal of Australia's low-level, and short-lived intermediate-level radioactive waste. The EIS was developed using a Geographic Information System (GIS) and includes a graphic display, tools and functions menus, menus to access theme data, and a decision and interpretation menu. The EIS, named *ASSESS*, highlights the benefits of having identified a clear purpose such as site selection. For the system to be appropriate for the user and its clients it should balance a simple design with the ability to perform complex tasks.

1. INTRODUCTION

A site for a low-level, and short-lived intermediate-level radioactive waste repository is currently being sought in Australia.

An early attempt to select a repository site in the Northern Territory was based on voluntarism but failed to proceed (Veitch 1995) because of the absence of a defensible decision process. It became clear that to be successful, the siting process needs to be fair, open and transparent; able to withstand scrutiny from the public, policy-makers, scientists and technical experts.

Used alone, a GIS can bring together the information needed to describe the features of the land and select a geographically suitable site, but a decision support system is required to work in conjunction with it to

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structure and present the decision-making process. Performance criteria for a site may be available, but who should interpret them, and how could they possibly represent the diverse values and opinions of the people affected by the site-selection decisions? The answer lies in the development of a GIS-based EIS that does not attempt to present a single prescriptive selection. Rather it allows the user to learn about the issues relevant to sites selected, to apply their understanding and then to determine for themselves where the consequences of their decisions lead.

The *ASSESS* system is easy to learn and fast to respond, providing scenario outcomes in a few minutes. This means that a variety of interpretations or decision scenarios can be explored. In each scenario the user learns more about the site selection task, the trade-offs and their consequences.

Through experimentation and learning a picture has developed of those parts of Australia that appear consistently suitable, or in other words show a robustness to the decisions and interpretations placed upon the information reflecting the site selection criteria.

The project to find a suitable site within Australia for low-level, and short-lived intermediate-level radioactive waste commenced in 1992 with the development of *ASSESS*. This scientifically based and publicly accepted GIS-based EIS demonstrates how a methodology with a decision-support system can be used for successful site selection.

2. GIS AND SITE SELECTION - WHAT IT IS AND WHAT IT CAN BE

GIS is now used regularly to assist the radioactive waste disposal site selection process (Openshaw et al, 1989; CNSI, 1993; National Academy of Sciences, 1996; Veitch & Bowyer, 1996) though with mixed success. Widespread concern about radioactivity means that a GIS-based EIS used for site selection and decision-making will attract scrutiny from governments, administrators, the public and the media.

Typically a GIS is used to assemble relevant theme data for the site selection criteria and these are then interpreted to define suitability categories. The interpreted suitability assessments are usually derived from expert judgements and are used to exclude unsuitable, and retain suitable areas. When several data themes are overlaid a spatial representation is achieved to highlight a range of potentially suitable to unsuitable areas. In its simplest form this is a GIS-based implementation of the ordinal combination method of site selection described by McHarg (1969). There are various other methods for generating suitability maps (Hopkins, 1977) and a GIS can be adapted to achieve their implementation.

If a GIS-based EIS has an interface that allows the user to modify or re-interpret information or functions then decision support and scenario planning becomes a part of the site selection process (Veitch, 1997). Hence, when computer-based Decision Support Systems (DSS) are used to support decision-making the scope for learning and adaptability expands (Sprague & Watson, 1986). There are several advantages to EISs such as these. They overcome the perception of predetermined or intractable outcomes, they can facilitate user involvement and learning, and they can be adapted to respond to changing needs as the decision environment changes. A successful GIS-based EIS assists the access of information, the understanding of a decision task and the ability to appreciate the consequences of selected options.

There are many relatively simple techniques that can be included in a GIS-based EIS that provide assurance to the user, to build their confidence and understanding of the decision task and outcomes. These are best when tailored to the application so it is necessary to have a clear understanding of the purpose of the EIS.

2.1 A Clear Purpose

Classical rational decision theory identifies three stages in the decision-making process: *Intelligence* - define the problem, *Design* - look at alternatives and *Choice* - select an alternative (Simon, 1960). These stages are identified in the design and implementation of an EIS incorporating decision support for site selection (Veitch, 1997).

An identifiable purpose or the need for a system to help solve a problem is the necessary basis from which to begin development of an EIS. This *intelligence* stage also includes data collection and examination, which then indicate the opportunities and limitations of the data. The *design* stage is an opportunity for experimentation where the design requirements for the system emerge from an understanding gleaned from the client and their needs: its level of sophistication, features, and how to implement the features through the user interface. The problem highlights the purpose, but decision-making for complex issues involves choice so a selection from which to choose must be presented.

The recognition of a clear purpose for an EIS with decision support is the basis for defining problems, identifying the data that is needed, and for applying a decision model. The EIS integrates the data and the model with software and a user interface. Its use enhances the user's understanding of the decision situation and presents decision outcomes.

3. LESSONS

3.1 Design of the User Interface

GIS packages typically incorporate a graphical user interface with point-and-click or pull-down menus. These provide the user with access to hundreds of commands or operations that can be applied to one or many data sets. Their design and layout is usually generic because of the wide variety of users with differing needs and background disciplines.

In vendor-provided menu interfaces a proficient user can quickly become frustrated when accessing often simple, mechanical or repetitive functions that are embedded in multiple menu layers. For their purpose command line syntax may be more efficient. This is so until a complex sequence of commands is repeated for an analysis method. It is then that a customised user interface with menus performing compound functions is preferable (Forier and Canters, 1996). There are now many EISs based on a GIS that employ a customised graphical user interface and menus. For example, Jankowski, 1995; Stein et al. 1995; Arentze et al. 1996; Watson & Wadsworth, 1996; Foster & McDonald, 1997; Alencar et al., 1997; Fischer, 1997; Foster & McDonald, 1997; Lenz, 1997; Swetnam et al., 1997; Veitch, 1997. The purpose of each EIS will indicate the necessary functions but common to all is their need to avoid being overly complex and cumbersome.

3.2 Layout

The limited amount of space on computer screens means that careful consideration is necessary to ensure an effective layout for the EIS interface. Figure 1 illustrates an efficient screen layout for a GIS-based EIS. The graphics window should dominate the centre of the screen and is therefore the centre of attention. This is where the outcomes of making decisions are presented so it needs to be clear and up-front. The menus and icons, arranged around the edges of the graphics window, should be placed so that related and commonly used functions are close together to reduce (mouse or touch-pad) travelling time.

The menu or sub-window that provides control for the decision operations should be large and uncluttered. For a right-handed user, these should display to the right of the graphics window. The means to operate the decision tools should be obvious or consistent so that extensive training or system familiarity is not necessary. Once a decision menu has been used it should be replaced by the next function unless it is necessary for reference in the decision task. If menus are to overlap then the important information of

the earlier menus should remain visible; as a minimum, their title. The overall appearance of the interface should remain uncluttered.

Menu sliders and toggle switches should be easy to operate and be supported with explanatory text in an easily read (sans serif) font size. Infrequently used functions are best placed across the top or bottom of the screen. The graphics window should also provide a title for the displayed information as well as an indication of the current operation and its significance to the decision task.

3.3 Tools and Options

A careful selection of GIS tools and commands should be enabled via menus and buttons. There is a risk of providing so many that the user becomes confused, or too few so that a regularly needed operation is unavailable. It is therefore important to anticipate the capabilities of the main users or to have different implementations to fulfil the requirements of different users.

At any stage a user should be able to interrogate a feature they are looking at, access its background information (e.g. attributes and metadata) and compare it visually (spatially) with other information. Annotation, measurement, location, magnification and printing tools are also useful. If the view is the result of a model operation or it has interpreted content then it should be possible to access information about the method used, the rationale and its basis.

3.4 Data Management

An EIS user need not have a knowledge of the directory and file structures that support the user interface. Nonetheless the results of their work should be well managed and retrievable. It is appropriate to have separate directories containing the files for reference data, interface tools and software, and separate areas for user-products. The tools for saving work should assist the user to document their modelling process and to store products for future access. It is often helpful to be able to use the EIS in the field or at remote sites. Where networked and portable systems are maintained, hard-coded paths to corporate data stores should be avoided. Instead, file path names should be variables so that re-coding is minimised.

Figure 1. An efficient GIS-based user interface showing a prominent graphics window, right-hand-side data access, decision menus, peripheral tools and display information

3.5 The Importance of Colour and Movement

Appropriate colouring of images in an EIS can convey powerful messages that translate to user feelings of acceptance - understanding and familiarity. For example, vegetation is commonly shown in shades of green, with areas of dense forest coloured dark green and grassland in pale green or yellow. Thus the viewer is provided with colour guidance in a range that represents data attributes. More detailed descriptive information is best provided in a legend (key) but the pattern of the colours, their tones and intensity conveys the immediate and powerful message of how much of what is where. Contrasting colours highlight differences and show boundaries. Urban areas and cities can be coloured dark grey, fauna reserves dark green, roads red, lakes blue and agricultural land brown. These are discrete categories and the choice of colour lends emphasis and reinforces characteristics. Road users are taught that red means stop, yellow caution and green go. To extend this concept, the same colours can translate from danger to safety, and for land use suitability, a range from risky to safe, unsuitable to suitable. Careful selection of colour assists the user's understanding of decision consequences in an EIS. If colour changes in

response to their decisions then the consequences of decisions are made immediate and clear. Changing patterns of colour, especially if the colours have meaning attached to them, strengthen learning, understanding and memory retention (Mednick et al. 1973).

The dynamic visualisation of processes is another powerful means of visual communication. When the consequences of decisions are shown as shape, colour and location that change in time and space then there is potential for enhanced understanding of the system's dynamics.

3.6 What's in a Name?

Successful EISs quickly become entities to which people want to regularly refer. Reference to the EIS by a descriptive and often long project name is cumbersome. Though initially it may be considered trite or a second-order consideration, providing the EIS with a simple name or acronym helps its mention and therefore others' knowledge of its existence and reputation. For *ASSESS*, the acronym was extracted from a longer title that referred to a part of the system's use: **A** System for **S**Electing Suitable Sites. The short form is also a verb that indicates its function as an EIS. The profile and identity that *ASSESS* has achieved has been verified in its use by other agencies to develop versions for their own site selection and land use decision-making.

3.7 Truth in Labelling

A major objective of an EIS should be to communicate that it represents an open and transparent information and decision support system. EISs typically present large amounts of information drawn from many sources. The age, quality, resolution, scale and reliability of these data may all range widely. Sometimes there is good documentation (metadata) for these characteristics but often there is not. The reputation of an EIS can be harmed if its source information and the methods that it employs are not defined.

Each data source should have metadata that includes descriptions of its lineage, resolution and quality. Similarly, the EIS modelling method should be fully described and provided as a part of the decision-making process. When an EIS is supported by good and readily accessible documentation then concerns that the quality and/or science are questionable are greatly reduced. Another benefit is that it is easier to repudiate accusations of hidden agendas or potentially flawed methods. Serious consequences can result for any EIS supporting a sensitive or contentious decision process if revelations are made by lobbyists or detractors about assumptions or poor quality information used by the system. It must be possible to review an EIS; the

review may never happen or it may not be detailed but the system should support it.

Periodic situation reports or demonstrations of results keep people informed and provide a feeling of ownership instead of provoking feelings of imposed decisions without their consultation. Feedback from reviewers should be encouraged and given genuine treatment. Even if their comments, ideas or criticisms are ill-founded, the very fact that the comments are made may indicate weak points of the EIS that could be remedied.

3.8 Data Scale, Resolution and Reliability

A common concern for those who present environmental information by GIS is that the assembled information may be used or re-interpreted inappropriately. Many techniques are possible in a GIS-based EIS that can prevent or at least alert the user to inappropriate use. These range from text-based advice which can be provided, on screen or in a user manual, through to making it impossible to use the data if quality limits are exceeded. One useful technique which can be used where the concern is scale and resolution, is to rasterise the data to an appropriate cell size. The data will then look increasingly blocky if it is presented at too small a scale.

3.9 Look for the Use-by Date

A GIS-based EIS is a potentially powerful aid to the decision-making process. It can provide a common platform for comparing otherwise disparate information and it can provide the versatility to try different interpretations as scenarios. There is a risk though that the EIS will be used in all situations, including some for which it is not designed.

Decision-making involves choices and ultimately there will be individuals or minority stakeholders who require personalised attention. The socially sensitive aspects of decision-making are difficult to formalise in computer-based systems. In these situations it is people to people, not people to system interactions that are required with the EIS still providing a useful backdrop and reference.

4. CONCLUSION

There are many lessons to be gained from the experience of designing and implementing a GIS-based EIS for radioactive waste disposal site selection. Few of these relate to the quality or features of computing tools and their performance. The lessons are about *people* and how they, as users and clients receive information and interact with computer-based systems.

The most important lessons are about the need for process transparency, objectivity, and versatility, and the integration of the user and the clients with the EIS. It is important to consider the features of the EIS in the context of its purpose for making decisions, the abilities of the user, and the features of the interface which can highlight outcomes.

For public, government, scientific and technical acceptability, the site selection method must be objective and transparent, able to bear review scrutiny, and be adaptable so that it can review and incorporate alternative suggestions. An EIS for a sensitive or contentious decision-making purpose should be straightforward and easy to describe.

The *ASSESS* EIS has been extensively tested by public and scientific review. As an EIS that is a successful land use and site selection decision support system it:

- has a clear purpose and well defined decision-making criteria;
- integrates knowledge, and accepts review from social, economic and scientific disciplines;
- includes the user in the decision-making process;
- uses a simple modelling technique;
- shows the results of decisions quickly using the graphical display;
- provides an uncluttered yet versatile user interface;
- employs GIS techniques to retain functions and validity at various scales;
- provides clear and accessible metadata and documentation;
- assists the user to document their results and processing history;
- enables scenario flexibility;
- uses colour to reinforce user understanding of decision consequences;
- has a name that makes it easy to refer to and identifies its function and role.

To be successful, a GIS-based EIS for sensitive issues must achieve a balance between the need for simplicity with the need for scientific and technical rigour.

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