

SDI development to Support Spatial Decision-Making

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Abstract

Improved economic, social and environmental decision-making are principal objectives for investing in the development of spatial data infrastructure (SDI) at all political and administrative levels. So much so, resolution 7 of the recent 5th Global Spatial Data Infrastructure (GSDI) conference in Cartagena, Colombia argued that the purpose of the GSDI is to improve the availability, accessibility, and applicability of spatial information for decision-making (GSDI 2001). Developing institutional support for decision-making that promotes and incorporates the availability and accessibility of spatial information therefore plays an important role in SDI implementation.

From an institutional perspective the motivation for SDI implementation is driven by the impracticality of a single organisation producing and maintaining the wide variety of data and models needed to inform many decisions, which results in increased sharing of data, information, analytical, display and modelling tools. This is being seen particularly in the natural resource, environment and local government sectors in Australia (Feeney *et al.* 2002). These sectors are utilising a variety of institutional mechanisms in their development of spatial decision support capabilities, which are moving progressively towards models that support the development and availability of interoperable digital geographic data *and technologies* to support spatial decision-making at different levels and participation.

The inclusion of technology support as part of developing SDIs has been recognised as essential to meeting the needs of the multi-disciplinary and multi-participant environments that characterise decision-making for sustainable development (Agenda21 1993, GSDI 2001, Rio+10 2002). Unless a diversity of decision support mechanisms are going to be incorporated more into decision processes many relevant and useful spatial datasets and technologies are not going to be used to their potential to support sustainable development.

Government has a central role to play in developing infrastructure that supports the discovery, access and applications of spatial information and technologies for such decision support. This paper looks at a variety of institutional mechanisms, for supporting the decision process, being employed in SDI development in the natural resource and environmental sectors in Australia. The decision-making levels supported by these different mechanisms will be reviewed in terms of organisational decision-making and decision process theories, as well as the level of coordination between institutional approaches at the spatial data policy level. The paper will conclude with a discussion of the implications of the approaches to developing institutional support for decision-making, as part of SDI development, as well as a consideration of directions for SDI development in the future to support spatial decision-making.

INTRODUCTION

Spatial Data Infrastructure (SDI) is developed to support ready access to geographic information to support decision-making processes at different scales for multiple purposes. One of the key purposes of the SDI is therefore to improve the availability, accessibility, and applicability of spatial information for decision-making (GSDI 5 2002). SDI is achieved through the coordinated actions of organisations (people) that promote awareness and implementation of complementary policies, common standards, and broad access networks through effective institutional mechanisms. It is the institutional mechanisms, in particular, which are of interest in this paper.

To address the functions of availability, accessibility, and applicability, institutional frameworks have been developed. Institutional frameworks are those supporting the organisation, promotion and use of public objects (Turner 1984), in this case digital geographic data and technologies. The role of the institutional framework in the development of the Australian SDI (ASDI) was recognised in 1996 (ANZLIC 1996) when it was identified as one of the ASDI's four key components, alongside the clearinghouse network, standards, and fundamental datasets, which were the other three components named.

The institutional framework of the ASDI includes the policy and administrative arrangements for building, maintaining, accessing and applying the standards and datasets (ANZLIC 1996). Whilst inroads have been made in promoting data availability, the shortfall in current institutional frameworks occurs in the promotion of the applicability of data to support decision-making beyond information discovery and visualisation, through to analysis and modelling.

This paper discusses the development of SDI institutional frameworks that not only support data products but also address the inclusion of technologies and services in order to support a broader range of spatial decision-making processes. It reviews the institutional mechanisms currently being used in Australia for developing appropriate institutional frameworks (including technologies) that support access to data and technologies, for spatial decision-making. The variety of decision-making levels supported by these different initiatives is reviewed in terms of decision process theory. The paper concludes with a discussion of the implications of the approaches to developing institutional support for decision-making as part of SDI development, as well as a consideration of directions for SDI development.

SPATIAL DECISION SUPPORT

Spatial information is potentially very useful for many applications within the community but has historically not been easily accessible to the majority of people without geographical information systems (GIS) software or skills. There are a variety of institutional mechanisms that bridge this gap in viewing and manipulating spatial data to support spatial decision-making processes within the user community. These include the development of atlases, spatial data directories, online services, community resource centres as well as the development of specific decision support tools. These approaches will be discussed subsequently, but move progressively from visualisation tools and interoperable digital geographic data towards those that also provide the availability of technologies to support spatial decision-making at different levels, including analysis and modelling.

The role of spatial technologies in the operations of the infrastructure has been recognised as essential to meeting the needs of the multi-disciplinary and multi-participant environments that characterise decision-making for sustainable development (Agenda21 1993, GSDI 2001). SDI cannot exist as a means in itself – it is essential the infrastructure support the development of spatial data products, services and the needs of diverse decision-making environments.

As SDI evolves people may access spatial data through the technical components (defined by Rajabifard *et al.* (2002) as access networks, policies and standards) either directly, or through technologies that will visualise, map or model the data prior to the data being used as information in decision-making activities. The current emphasis for people accessing data through SDI is on the technical components (Rajabifard *et al.* 2002). However, the authors believe these will become increasingly transparent to data users, as access is increasingly sought to 'simplified answers', or data shaped (integrated, analysed, modelled) through technologies like decision support systems, rather than in its raw form. The transition to this model of 'applied' data access and use, a decision support enabling SDI (DSE-SDI) will require institutional mechanisms to support the availability and access to integrated data and interoperable technologies. Clearinghouse development, online services, decision support technologies and community resource centres are examples of institutional mechanisms that may contribute to the transition.

INSTITUTIONAL MECHANISMS TO SUPPORT DECISION-MAKING PROCESSES

Many communities are now using spatial information to help address business needs regarding resources or industries. The Murray Darling Basin Commission (<http://www.mdbc.gov.au/>) and the Fitzroy Basin Association (<http://www.fba.org.au/>) were instigated by regional community cooperation towards spatial information sharing and development of decision support networks. These two examples have developed across local and state jurisdictions, driven by the urgent need for a coordinated and participatory approach to natural resource and environmental decision-making. The SunRISE21 project (Victoria), Herbert Resource Information Centre (Queensland) and the Central Highlands Regional Information Service (Queensland) are three other examples of communities using spatial information to assist decision-making (Barker *et al.* 1999). These and similar projects (for example the number of initiatives discussed by Barker *et al.* 1999) demonstrate the desire by an increasing number of communities to have access to spatial information and the tools and skills which allow for them to plan better and make more informed decisions.

Government agencies are the custodians of large amounts of spatial data useful to the community. Recent technological developments have democratised the ways communities access information and knowledge (Barker *et al.* 1999). The demand has grown for more flexible service delivery from government, including access to tools, spatial information and the skills to interpret the information. Recent work has proposed ways by which government can interact with community and industry to improve the flow of information (Barker *et al.* 1999), particularly spatial information, between data custodians and users. Government has an important role to play.

There are a number of delivery mechanisms currently used by communities to get access to spatial data and knowledge. These range from individuals including consultants, government representatives and data brokers, who have access to data, GIS and other spatial technologies and interpretative skills, through to online services delivered through web sites either created and maintained by communities and centred on the business and information needs of that community, or government web sites. Resource centres for communities are a further example where a suitable combination of integrated data sets, internet tools, web sites, data-provider extranets and facilitators/consultants are selected to help users with their information needs. These mechanisms are part of the SDI institutional framework being developed to support access to data and technologies for structuring spatial data for decision-making.

To this end, governments are providing support for decision-making through institutional mechanisms providing access to spatial information and facilitating varying degrees of spatial data applications. These institutional mechanisms include the development of atlases, spatial data directories, online services, community resource centres as well as the development of specific decision support tools. These approaches are discussed in the following section with a particular focus on the degree each institutional mechanism promotes data availability, access to data, and in some instances also technologies, for structuring spatial data for decision-making processes at different levels. Examples of each of the institutional mechanisms are provided.

Atlases

Atlases are a network of spatial data nodes that give the public map-based access to view a wide variety of data held by different custodian agencies. The data may be gathered in different formats, represent different variables and be presented at a range of scales. At any particular chosen scale the atlases present to a user the datasets which are available.

Atlases function as a way of discovering, selecting and visualising spatial data, with many providing facilities for overlays and map customization. They are principal tools in the information discovery phase of the decision process, detecting data availability and coverage, especially for linking levels of data between local, state and national jurisdictions. For instance, the Australian Coastal Atlas is a network of Commonwealth and State/Territory nodes using a variety of interactive desktop mapping tools to provide information about the Australian coastal environment. The Atlas includes maps and images of the coastal zone showing information about water quality, climate, fisheries and more. It enables users to view layers of information about the Australian coast, as well as assemble and print user-developed custom maps. The Tasmanian node of the Australian Coastal Atlas is pictured in Figure 1, as part of the Land Information System of Tasmania (LIST).

Different agencies within each state jurisdiction have custodial responsibilities for the data that is presented in the atlases and thus different institutional arrangements. The national node of the Australian Coastal Atlas has recently been integrated with the Australian Natural Resources Atlas (<http://www.ea.gov.au/coasts/atlas/>). However, the Queensland node of the Australian Coastal Atlas (<http://acaweb.dpi.qld.gov.au/atlas/atlaspage.html>), is coordinated by the Environmental Protection Agency and the Department of Primary Industries (DNRM 2001), whilst the Queensland node of the Natural Resource Atlas (<http://www.dnr.qld.gov.au/resourcenet/atlas/>) is coordinated by the Department of Natural Resources and Mines'. Taking a slightly different approach, both the Northern Territory nodes of the Coastal

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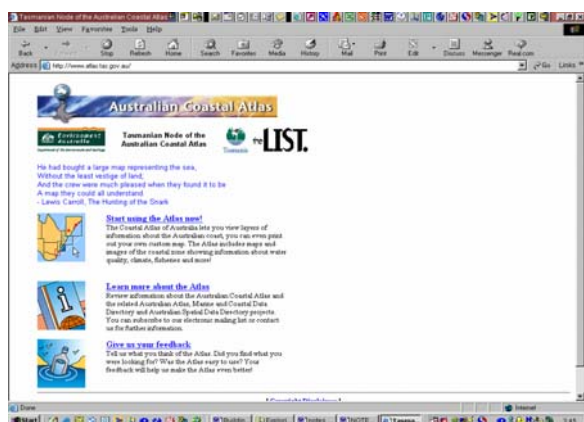


Figure 1: Tasmanian node of the Coastal Atlas.

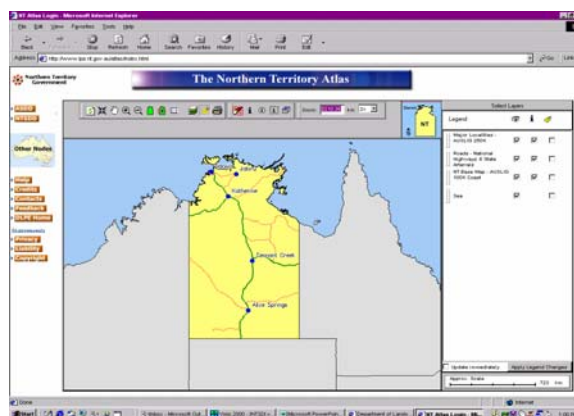


Figure 2: The NT Atlas.

Atlas and the Natural Resource Atlas, occur under the umbrella of the Northern Territory Atlas (<http://www.lpe.nt.gov.au/atlas/index.html>), (Figure 2), which is coordinated by the Department of Land, Planning and Environment.

Whilst the nodes may be accessed via different entry points in each state (generally as a function of the institutional arrangements), what is important is that the atlases provide a network through which publicly available spatial data, relevant to particular locations, is discoverable and viewable both within and between jurisdictions. This is exemplified by the Western Australian Boating Atlas (http://www.transport.wa.gov.au/imarine/coastal_fac/boating_atlas/index.html), which presents information about recreational and commercial boating facilities around the state from local governments, state porting authorities and Department of Transport, alongside tidal information from the Australian Hydrographic Office. This atlas provides details of boat harbours, boat ramps and other boating facilities, with links to tides and wave data.

At a regional level the Queensland Central Highlands Regional Resource Use Planning Project (CHRRUPP) has produced the Central Highlands Atlas (<http://chrrupp.tag.csiro.au/Resources/>) that presents online maps featuring basic coverages of vegetation, soils, land systems and socio-demographic data. The process of overlaying data to form maps gives the user the opportunity to examine whether the data is fit for a particular use and contributes to the preliminary design and development of different scenarios in the decision process. CHRRUPP supports a range of stakeholders and assists them in managing regional natural resources and making decisions with a focus on regional planning for sustainable natural resource use. CHRRUPP coordination is via representatives/observers from a range of groups and agencies such as: pastoralists, graingrowers, aboriginal community, food and fibre producers, mining industry, local government, state government, federal government, Central Queensland University and Landcare (DNRM 2001).

Individual local government areas (LGAs) have also begun to make spatial information available to the public via atlas facilities. Caloundra City Council (Queensland) has established an atlas facility (<http://maproom.caloundra.qld.gov.au/Other/entry.htm>) using ArcIMS, where clients can inquire about tourist and environmental information within the Caloundra LGA (DNRM 2001).

Spatial Data Directories

A spatial data directory is a tool to improve data discovery for the spatial data industry, government, education and the general community by collecting and storing information about datasets (metadata). Such a directory is supported through effective documentation, advertisement and distribution of spatial data. The agency coordinating the directory is able to increase the knowledge infrastructure for a community by enabling members to better identify appropriate datasets and communication links with custodial agencies, often facilitating data accessibility, and the information discovery as well as the design and development of different scenarios and choices in the decision process.

The Australian Spatial Data Directory (ASDD) is a national example (<http://www.environment.gov.au/net/asdd/>), with nodes supported and maintained by all governments under the auspices of ANZLIC (Australia and New Zealand Land Information Council) as well as the private sector (for example AIRESEARCH (ANZLIC 2000)). The directory is a distributed system of links between government and commercial nodes in each state/territory as well as spatial data agencies within the federal government. The directory incorporates information about datasets (metadata) from all jurisdictions and is thus a key component linking local, state and national SDIs.

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This is further exemplified through Interragator Online, the Western Australian spatial data directory (WALIS 2001), which has both textual and spatial search capabilities and is the access point for geographic and land information in the state. With Interragator Online a comprehensive index to over 10,000 records of Western Australia's geographic and land information held by public and private sector organisations can be searched, using metadata for locating digital maps, spatial databases, aerial photography, satellite imagery and environmental impact statements. Interragator Online is part of the ASDD, thus linking various directory services around Australia, but is further searchable from the USA Federal Geographic Data Committee (FGDC) Entry Point to the Geospatial Data Clearinghouse (WALIS 2001). This entry point provides several interfaces to search for spatial data, which demonstrates the consistency attainable between different jurisdictions' metadata initiatives and the potential for a global directory service once compatibility is achieved at the international level.

Other examples of directories in Australia include the Australian Geographic Information on the Web (<http://www.gsdi.org/canberra/asdd.html>) and the InterNet Resources for Land Information Systems (<http://www.library.unisa.edu.au/internet/pathfind/land.htm>). At the state government level the New South Wales Natural Resources Data Directory (<http://www.nrims.nsw.gov.au/nrdd>); the Northern Territory (<http://www.lpe.nt.gov.au/servlet/NTSDD>), South Australian (<http://www.environment.gov.au/net/asdd/tech/node/sa-1.html>), Victorian (<http://www.giconnections.vic.gov.au/>), and Tasmanian (<http://www.thelist.tas.gov.au/>) Spatial Data Directories; as well as the data menu for the Queensland Spatial Information Infrastructure Strategy (<http://www.qsiis.qld.gov.au/cgi-bin/php/index.phtml?menu=QSIS+Home>) are several examples. These are further augmented by detailed government department directories such as that for the Victorian Department of Natural Resources and Environment (<http://www.nrsc.com.au/>).

Whilst these spatial data directories are primarily services for distributed data discovery, using metadata, they may be extended to form the basis of a clearinghouse, which is a distributed model for data access. In principle a spatial data directory may be developed into a clearinghouse through the addition of several new metadata elements, the key being the URL providing the link to Web sites for data access/ordering (ANZLIC 2000). Clearinghouses are considered a key component of the Australian SDI (ANZLIC 1996) as they are considered the technological framework established to give the community access to fundamental datasets. This is achieved where data from distributed databases is linked and integrated by common standards and policies in order to be accessible to the community (ANZLIC 1996). Whilst improved data dissemination is facilitated by a clearinghouse in the short term, on-going access to the data will eliminate the need for users to incrementally update their data copies because they will always have access to the most recently maintained data, as well as value-added data.

Online Services

In practice the technical difficulties of interoperability and the lack of comprehensive standards mean there are fewer successful examples of clearinghouse models than directories and integrated online data visualisation (atlas) and service facilities (for example online land information services) developed in the different states in Australia. Access to direct data down-loading is also still frequently constrained by the development of institutional agreements, the implementation of pricing and licensing policies, and the market definition of user needs. The development of online land information, as one of a number of online services, has provided the intermediary systems for accessing different forms of land information (often summaries, graphs, tables or reports rather than raw data) and technological services for the presentation or desk-top manipulation of that information. These functions facilitate the generation of different scenarios and choices in the decision process through the examination of available data and the limitations that may influence the decision alternatives generated from these.

The activities of Community Access to Natural Resource Information (CANRI) in New South Wales, in the provision of data discovery, visualisation and preliminary data delivery and dissemination mechanisms through a generic graphical user interface, are an example of such online services, centred in the domain of natural resource information. The CANRI technology framework is based on the Integrated Community Mapping and Information Support System (ICMISS), which pioneered distributed web mapping with its release in 1998-99 and has been an influential model for the development of international standards for web mapping by the OpenGIS Consortium (CANRI 2002). CANRI applications like the New South Wales Natural Resources Atlas use the New South Wales Natural Resources Data Directory (NRDD) as a catalogue to discover and access online datasets. However, in addition to the ANZLIC-standard metadata, accessible to NRDD users, CANRI applications use metadata extensions designed specifically for online data access. (Though at present this does not extend data-download access directly to users due to the nature of many of the institutional agreements with data providers for many of the datasets). The ongoing modification of the format of this metadata and the interface to comply with the OpenGIS Catalogue Interface specifications enable CANRI applications to also make use of other catalogues of data and services as they emerge.

CANRI has been conceived as a framework for information sharing to meet the increasing need for easy, integrated access to a wide range of natural resource and environmental data. CANRI uses the Internet to connect the

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information resources of many different organisations in situ, without requiring them to surrender data to a centralised depository, but additionally without need for users to 'click through' from site to site to source data they are after – access to data is through the single CANRI web site. The CANRI framework supports access to a wide range of remote data servers over the web; any data server which complies with the OpenGIS Web Map Server specification is supported (CANRI 2002). A growing number of GIS vendors are now providing such products and alternative low-cost bridges can be built for most data sources. This enables the CANRI framework to make use of independent information services available on the web, therefore not only making government information available to the community, but enabling community groups and individuals the opportunity to contribute their own information and share it with others through the CANRI website. The flexibility of the CANRI model will accommodate the transition proposed by the authors from SDI being predominantly a raw data facility to an infrastructure providing access to derived data, models and data applications and services. The DSE SDI accommodates the evaluation, analysis and modelling of different scenarios and choices in the decision process and the comparative analysis of alternatives.

The key priorities of CANRI users are perceived to be web-based discovery of suitable data, easy access to visualisation tools, and some downloads of key data sets (New South Wales State of the Environment data are one example utilised frequently by local councils) (CANRI 2002). In terms of the provision of online technologies, a geographic projection service is currently built in to the CANRI application server and this area of the architecture is expected to grow with the availability of gazetteers, address geocoding, image processing and other services (CANRI 2002).

The land information systems service centres developed to facilitate spatial data product discovery, access, visualisation and services in relation to government transactions, are a particular example of the online services that have achieved widespread interpretation through different jurisdictions in Australia and around the world. Service New Brunswick (SNB Canada), Land Information Systems Tasmania (LIST, Figure 1), the Western Australian Land Information System (WALIS, Figure 4) and GIconnections (Victoria, Figure 3) represent three examples of these, generally cadastre-based spatial information systems (GIconnections 2002, LIST 2001, SNB 2001).

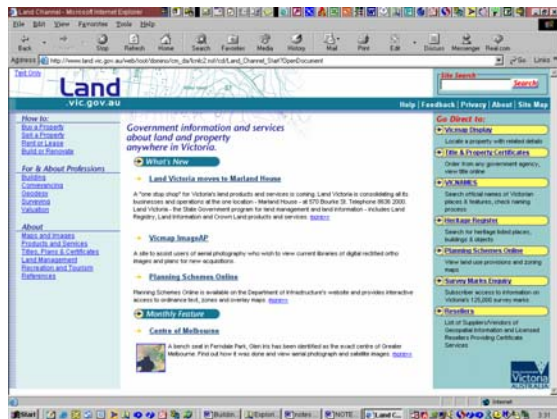


Figure 3: The LIST - Land Information System Tasmania



Figure 4: The WA Land Information System, WALIS.

Within the Queensland Government, a number of agencies are creating, or have created, applications that provide interpreted spatial information on GovNet and/or the Internet. These applications target general as well as specific audiences. They include: Department of Primary Industries' Coastal Habitat Research Information System (CHRIS, <http://chrisweb.dpi.qld.gov.au/chris/>), Public Works' Queensland Building Information System (QBIS, <http://www.build.qld.gov.au/amps/qbis.htm>), Sport and Recreation Queensland's Outdoor Resource Inventory System (ORIS), Natural Resources and Mines' Burnett Catchment Web GIS (<http://www.dnr.qld.gov.au/resourcenet/land/Iris/webgis/burnett/maps/mapdisplay.html>) and the Interactive Resource and Tenure Maps of Queensland (http://www.dme.qld.gov.au/resdev/qmin_ims.htm) (DNRM 2001).

Aside from online land information projects, the Federal Government has established a Government Online Project which aims to make information concerning all appropriate Federal Government services available online by 2002 and to establish a single point of access to information about Government agencies (AUSLIG 2001). The development of whole-of-Government standards and systems will provide online access to Commonwealth geographic data holdings. The project aims to provide some simple, interactive mapping applications where data is sourced from various custodian agencies, integrated and delivered via the Internet (AUSLIG 2001). This will build

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experience for more complex projects, test the technology for more widespread use and test data access issues within the Commonwealth.

Community Resource Centres

The main aim of Community Resource Centres (CRCs) is to assist community empowerment by making tools, information, and the skills with which to interpret information, more accessible. Ideally resource centres for communities provide opportunities for stakeholders to share and exchange information, so the process is not simply one of dissemination. If a CRC is to improve access to information for a community so that they can participate in planning and decision-making processes, Barker *et al.* (1999) believe it must have skills, technology, products and tools, data and credibility. These elements are elaborated on in Table 1.

The Herbert Resource Information Centre (HRIC) is an example of a CRC. It is a catchment-based GIS facility that supports the management of natural resources in the Herbert River catchment by providing and allowing access to geographic information, GIS tools and expertise (HRIC 2001).

The HRIC was derived from the Herbert River Mapping Project (1993-1996), formed to facilitate the collection and sharing of data between eleven agencies from industry, community and the three tiers of government (local, state and federal) (Walker *et al.* 1999). During the course of the project it became clear the access and on-going facilitation of benefits from the data, especially advanced analysis of the digital data through GIS, decision support systems and complementary spatial technologies would require an evolving collaboration to manage the resource data (Walker *et al.* 1999, 1998, 1997).

The HRIC currently involves six partners from three tiers of government, industry and primary producers to facilitate a common geographic view of the catchment and to enable synergistic planning amongst partners and the community (Walker *et al.* 1999). Whilst the HRIC does not resource data capture and maintenance directly, it acts as a project manager to coordinate these activities. The HRIC has also enabled the introduction of supporting technologies for users of the centre facilities, as well as consultation about the application and modification of such technologies for appropriate decision-making. The commitment of the HRIC to assisting the interpretation of data according to user decision-making requirements is a distinguishing feature of the CRC model and its support of the design and development of different scenarios and choices in the decision process.

One particular example of the introduction of technology to support decision analysis and alternative generation has been the web-based spatial decision support system, NRM-Tools (CSIRO 2001). NRM-Tools has been designed to explore issues and options in integrated natural resource management and is being run as a prototype through the HRIC such that the data and tools being run within the current version are focussed on integrated resource issues from the Herbert River catchment (CSIRO 2001).

Another example of a CRC is the Integrated Information Management System (IIMS) initiative developed between 1996-1999 for catchment managers to accommodate the lack of resources (data, models and human skills) available (or accessible) to adequately respond to management issues (IREM 2000). It was funded by the Land and Water Resources Research and Development Corporation, and has been developed in collaboration between the Department of Natural Resources (Queensland) and the University of Queensland in consultation with stakeholders and potential users (IREM 2000).

The aims of IIMS are to facilitate the use of research outcomes and government information by Catchment Management Committees (CMCs) and allow them to identify the resource use options available to stakeholders (other CMCs, rural landowners and local governments) to improve the management of their land and water resources (IREM 2000). One key motivation for the project was the few attempts made in Australia to integrate social, behavioural and economic data into spatial decision support systems (and thus support the design and development of different scenarios in the decision process) that could assist planning decision-making (IREM 2000).

The results of the IIMS development were three prototype facilities developed for catchments in Queensland and New South Wales. IIMS prototypes for assessment in the Dee (Queensland), Dawson (Queensland) and Liverpool (New South Wales) catchments (IREM 2000) were established as web-based facilities where information, links to related information/legislation/technologies, research and particular DSS could be established to

SKILLS - it will build the skills community members need to interpret data, whether by building the capacity of consumers to make appropriate use of analytical tools & data sets, or by providing consultants (e.g. GIS specialists) to assist this process;

TECHNOLOGY - it will supply technology - hardware, software (but not necessarily the infrastructure) - to support the access to & analysis of data for community needs;

PRODUCTS & TOOLS - it will provide products & tools to assist the flow of information between custodians & users of data, & to assist the interpretation of data according to user requirements;

DATA - it will provide information in the form/s that users require;

CREDIBILITY - it includes protocols for security, intellectual property & management of documentation of knowledge & supporting processes. The centre should also have credibility in its business practices, with protocols for marketing, distribution of funds (with appropriate return of royalties & licensing fees), etc.

Table 1: Essential elements necessary in effective CRC development (from Barker *et al.* 1999)

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aid catchment decision-making. The IIMS provides web-link access to and advertises workshops for a Multiple Objective Decision Support System (MODSS) named Facilitator (IREM 2000).

Well-established models of similar regional spatial data and technology initiatives exist, such as the Central Highlands Regional Information Service (CHRIS, with its online decision support system Java AHP) in Queensland (CHRIS 2001, CHRRUPP 2001) and Service New Brunswick in Canada (SNB 2001). Although there are distinctive characteristics for each CRC and the objectives behind them, similarities between models can be identified. Figure 5 demonstrates the Barker *et al.* (1999) model of a generic community resource centre.

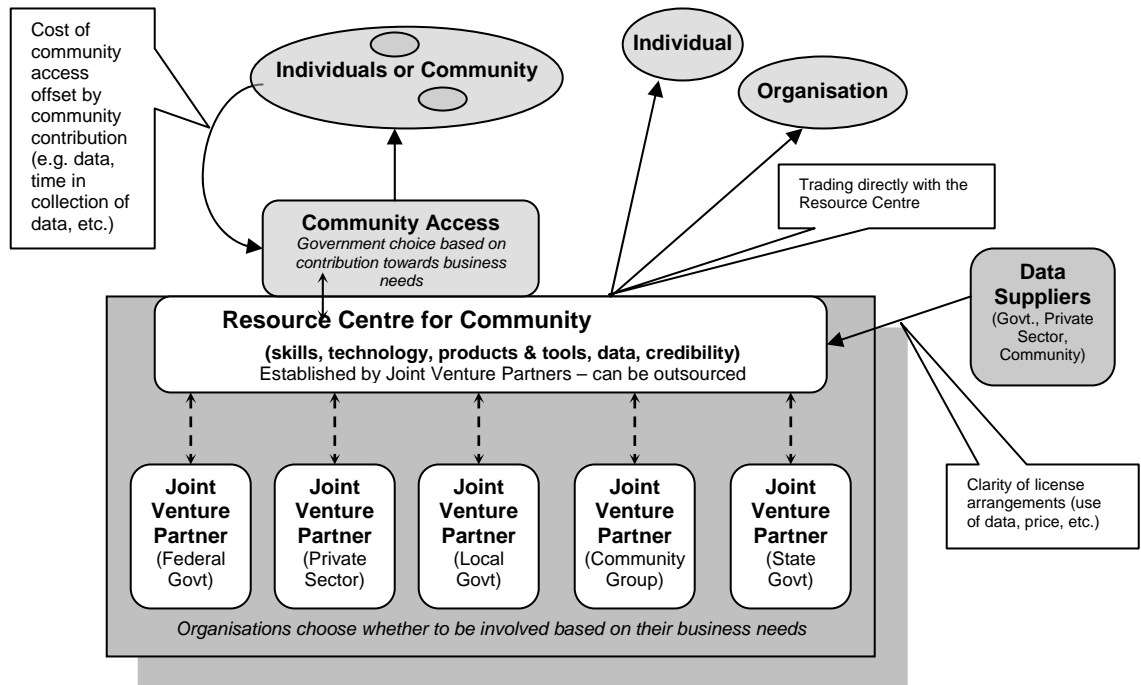


Figure 5: Generic model for resource centres for communities (from Barker *et al.* 1999)

Decision Support Technologies

Decision support technology, often integrated into systems (and therefore called *DSS*) can be generally defined as “an interactive, computer-based tool or collection of tools that uses information and models to improve both the process and the outcomes of decision-making” (Lessard and Gunther 1999). *DSS* are therefore developed to contribute to the design and development of different scenarios and choices in the decision process in particular. *DSS* are generally composed of a number of components:

- An interface between the human and the computer;
- A model base (the models of phenomena, rules);
- A database;
- Communication among components;
- An analytical engine (to assemble the models and data and conduct the analysis); and
- Output and visualisation capabilities.

The *DSS* can reside within one computer, within an enterprise, or in a much broader context such as distributed regionally, or even globally, across the Internet, however, it exists within the human problem-solving environment.

DSS's have been developed and deployed for some time, particularly in the private sector, in business activities in the public sector, and in the military. Applications to public policy issues are newer, including economic policy models to provide support for monetary and fiscal policy decisions. In recent years, there has been a considerable increase in interest in combining the capabilities provided by *DSS* with those from GIS. The results, still evolving, are a new class of *DSS*, referred to as Spatial *DSS*, which apply to geographically defined areas, such as catchments, cities, forests, or national parks.

Spatial *DSS* differ in several important ways from other *DSS*, as a result of the type and context of the problems they address: they apply to entire communities, public lands, or publicly owned natural resources; they

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must attempt to bring together the disparate values and objectives of multiple stakeholders; and they need to incorporate multiple sources of expertise (for example hydrology, economics, biology and engineering). Spatial DSS are an example of how DSS are evolving: from systems typically used by one or a small number of specialists, which focus on narrowly defined private sector objectives using proprietary databases, to those that are capable of reflecting broad social objectives, which encourage collaborative decision-making about the places we live and work. Citizens and community groups are increasingly demanding a voice in these decisions, and developers are responding.

An example is the development of Catchment and Natural Resource spatial DSS in Australia. Already mentioned in relation to CRCs have been the online DSS Java AHP as well as the natural resource management tool box, NRM Tools, and the Multiobjective DSS, Facilitator. Government departments have also been involved in the development of spatial DSS, which are becoming important institutional mechanisms for interdepartmental sharing of information, analyses and communication with stakeholders on cross-disciplinary issues.

Victoria's Department of Natural Resources and Environment (DNRE) have developed Catchment Decision Assistant (CDA), which is a windows-based software package for building decision trees, defining and recording criteria and ranking projects, issues and sites (Itami *et al.* 1999). The CDA software is an implementation of the Analytical Hierarchy Process (AHP), a method that helps experts identify criteria and weight the relative importance of each criteria for complex decision-making (Itami *et al.* 2000).

The motivations for developing CDA were provision of better access to information on catchment conditions, expert interpretation of the data for decision makers, high quality outputs in the form of maps, tables and graphs, and promotion of an information-based approach to decision-making using the best available knowledge (Itami *et al.* 2000). These motivations have been the same for the New South Wales Department of Land and Water Conservation, which has similarly been developing a business case for using comprehensive spatial analysis in catchment-scale planning, and specifically for adopting the LAMPS Targets Analysis Process (TAP) as the standard method for this type of analysis in New South Wales (DLWC 2001).

The TAP, (and its supporting 'Targets Toolkit' of ArcView software and Excel templates) has already been prototyped and fully trialed in the Murray and Murrumbidgee regions, and has been partially trialed in the Central West (DLWC 2001). It involves a method of harnessing the available expert and local knowledge to rapidly produce valid maps showing the relative impact of a single action across the landscape towards a single target. These maps can be overlaid to analyse relationships between actions (such as co-benefits and synergies) to determine where maximum advantage will be obtained. A wide range of analytical and statistical tools is available as a direct result of regional requirements identified during the prototyping phase (DLWC 2001). Grid based analysis under the flexible and widely available ArcView GIS environment allow more detailed techniques to be easily integrated into the framework – the TAP is not intended to replace scientific modelling, but to offer an alternative in cases where modelling is not available.

Despite these and other examples of the tools and systems available, or under development, to support decision-making, no one system will provide the broad range of capabilities required by decision-makers and stakeholders, nor will one agency or developer have the resources or mission to develop and maintain the range of tools needed by the decision-maker. These considerations, in conjunction with the current and evolving technology, fixed and shrinking budgets, and increasingly complex challenges of resource management (Gunther 1999) combine to provide an opportunity for expanded cooperation in accessing and developing interoperable decision support tools and systems. They also provide the impetus for models and derived datasets to be equally available and accessible through SDI. The latter will only foster an open and competitive supply chain of value-added data and decision-support resellers and stimulate an evolving market of spatial data and service provision.

IMPLICATIONS FOR SDI DEVELOPMENT

The institutional mechanisms discussed above provide different levels of support for the decision process in terms of the discovery, access to and applicability of information available as well as the desired intent-of use. Obviously, there are many existing methods to distribute data and knowledge to communities to assist spatial decision-making. Ideally, the SDI institutional framework provides the facilities for stakeholders to share and exchange information, so the process is not simply one of spatial data dissemination.

Atlases and directories provide the means for text and often spatial searches for data to satisfy the information discovery phase of the decision process which is directly related to data being available for discovery. These institutional mechanisms as yet fall short of providing access to data which is downloadable for analysis and modelling or to derived data products where this analysis has already been done by value-adding resellers, or where models could be found to contribute to the design and development of different scenarios and choices in the decision process. The capability for directories to provide more than unidirectional links to other sources of data and accept the addition of independent data provide the foundations to support a competitive data market and preliminary clearinghouse development for access and two-way (download-upload) data exchange, but as yet are not widely

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used. Until such a time, however, the design and development of different scenarios and choices in the decision process are limited to what can be based on available data visualisation in customisable data atlases, and the proposed current SDI model of users accessing data directly.

The online services, the community resource centres and decision support technologies have a different emphasis to the atlases and directories. These institutional mechanisms have greater capability to extend data availability and information discovery phase of the decision process to making tools, information, and the skills with which to interpret data, more accessible, as well as offering broader support to the full decision process. In terms of decision support technologies and systems, this refers more to extending the interpretative capabilities to those without the analytical or modelling resources or experience, or alternatively extending the datasets derived from such analyses. In the existing model of SDI the ability for DSS to contribute these advantages to supporting spatial decision processes is much reduced by the focus of SDI on users accessing datasets directly. The DSE-SDI model enables the exchange of derived datasets, models, and other data services that not only increase the capacity of the spatial data market, but also the ability for different phases of decision-making. Participants with different levels of spatial data processing skills are able to access the data directly, or through technologies able to visualise, model, analyse and/or summarise spatial data. The variety of mechanisms enabling the presentation of spatial data to be used for decision-making activities ultimately makes the derived DSE-SDI model more flexible to the evolution of the spatial data market and adaptable to the changes presented by users and the ongoing development of spatial technologies to support presentation and decision-making.

Future directions for SDI development following the proposed DSE model will continue to require greater institutional framework development through mechanisms to meet the challenges of diverse decision-making environments and spatial data interpretation. Issues such as urban renewal, forest management, native title administration, coastal economic zone management, defence, drought relief and landcare cannot be addressed without available, accessible and applicable spatial data that support the decision process. This will require that greater consideration be given to the range of mechanisms available to support decision processes, provide interpretation, analysis and flexible applicability of spatial data to decision-making in SDIs, as well as the perception of the infrastructure as purely a data facility.

CONCLUSIONS

The concept of a derived SDI model with institutional and technical frameworks enabling the production of spatial data products, services, the long term support of spatial industry processes and decision-making needs to be examined and debated. The ability of SDI to support decision-making processes and a varied user environment is dependent on the current and developing capabilities of SDIs to support spatial data and derived data products, models and decision support technologies, through the mechanisms developed within institutional frameworks.

The interaction of the spatial data users and suppliers and any value-adding agents in between, drive the development of any SDI. These present significant influences on the changing spatial data relationships within the context of SDI jurisdictions. This paper looks at how availability and accessibility of spatial data are being achieved by examples from a range of institutional mechanisms. These mechanisms include spatial atlases, spatial data directories, online services, community resource centres, decision support technologies and DSS. The variety of decision-making levels supported by these different initiatives is reviewed in terms of their support for parts of the decision process. While accepting that these mechanisms support decision-making by promoting the availability and accessibility of spatial information to support the discovery of data, and the preliminary evaluation of data that may be used, and how, to support the decision-making activity, the mechanisms largely fall short of addressing the applicability of spatial data to the generation of decision choices in the decision environment.

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