Researching Frameworks for evolving Spatial Data Infrastructure

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Presented at SIRC 2000 – The 12th Annual Colloquium of the Spatial Information Research Centre
University of Otago, Dunedin, New Zealand
December 10-13th 2000

ABSTRACT

Technology and infrastructure both play key roles in achieving the optimisation of spatial data to support decision-making, in the spatial data community. Many institutional and technical initiatives have arisen in response to the increase in quantity and improving quality of spatial data to help users to structure the influx. However, there are persistent challenges to integrating institutional and technical solutions to optimise the utilisation of available spatial data. Embracing and continuing to develop a flexible, methodological, framework for the integration of decision-supporting technologies with infrastructure is fundamental to supporting effective incorporation of spatial data in decision-making. This paper reviews the nature of current developments of Spatial Data Infrastructures (SDIs) and Spatial Decision Support Systems (SDSS) and discusses issues pertinent to the optimisation of spatial data utilisation, access and management to support spatial decision making environments. A research procedure is proposed to investigate the hypothesis that increasing the functionality of SDIs to support the use of spatial data for decision-making can be facilitated by developing methods for the integration of SDSS. Literal and meta-level models are developed of the data flows between SDSS, SDIs and decision makers from data gathered via a case study methodology. The research will provide the means for designing a methodological framework that will enable integration of SDSS by SDIs to enhance facilitation of the capacity for spatial data utilisation in decision-making.

Keywords and phrases: Spatial Data Infrastructure (SDI), Spatial Decision Support Systems (SDSS), Literal and Meta-level Models, Case Study Methodology

1.0 INTRODUCTION

During the transition from a data poor society, especially spatial data, to one now comparatively data rich, the means of organising, storing, accessing, managing and actually using data to which there is now access have not kept pace (Openshaw 1998, UCGIS 2000). Technical and institutional initiatives developed to address different aspects of spatial data sharing and management have contributed to improved spatial data utilisation. However, without integration to meet user needs for the support of decision-making, persisting independence may impede future opportunities for technical and institutional initiatives to optimise the utilisation of available spatial data.

Many institutional and technical initiatives have arisen in response to the overwhelming increase in quantity and improving quality of spatial data to help users to structure the influx (Openshaw 1998, Phillips 1998, Gittings 1999). Institutional initiatives that have contributed to the management and utilisation of spatial data have included development of standards, industry partnerships, access protocols and policies on infrastructure. Technologies have been developed that have aided the management and utilisation of spatial data. For instance, faster and cheaper computing, the shifts from mainframe to desktop, the development of the Internet and many other breakthroughs have made it easier to process and store geographic information in digital form. The development of Geographical Information Systems (GIS) have taken users of geographical information a tremendous step forward in their ability to analyse, map and model the spatial world.

However, there are persistent challenges to *integrating* institutional and technical solutions (Baptista 1999, Gittings 1999, Tosta 1999, Coleman and McLaughlin 1998) to optimise the utilisation of available spatial data. These challenges include access, availability and discovery of the spatial data required to support decision-making; data quality and its documentation; data standards and metadata development; as well as the social and political issues surrounding spatial data sharing. The motivation for addressing these challenges has been the need to address the question: “What actions are needed to facilitate sharing and utlisiation of spatial data to support decision making?” One response has been the development of the concept of Spatial Data Infrastructure (SDI) to facilitate the integration of institutional and technical initiatives toward greater use, access and exchange of spatial data within the community of spatial data users and producers (the spatial data community).

The design and implementation of an SDI is not only a matter of technology but also one of designing institutions, the legislative and regulatory framework and developing new types of skills (Remkes 2000). Balancing these elements to develop SDI enables the dynamic intra- and inter-jurisdictional sharing of spatial data facilitated by SDI, to be achieved in a number of ways. SDI functioning at a very strategic level is about the formulation of policy, technical standards, access networks and channels of communication to facilitate spatial data sharing between people. At tactical and operational levels the principles behind the SDI concept must translate to better data management to achieve business and organisational objectives effectively. For spatial decision making such data management translates to increased capacity for resource discovery, interoperability, access to data lineage, spatial process and quality documentation. This requires that SDIs address the integration of technical and institutional initiatives for effective data management and to support decision-making processes.

As spatial decision-making becomes quite complex, the need to solve semi-structured and unstructured problems becomes a frequent requirement of many disciplines (El Swaify and Yakowitz 1998). Planning for and management of natural resources, the environment, emergency services, utility maintenance and development, health facilities and the financial sector, are examples, to name a few. Thus, creating the ability to access tools to shape and model spatial information for particular disciplines, through the integration of technical and institutional instruments for spatial data utilisation, becomes advantageous as well.

Spatial Decision Support Systems (SDSS) are an example of tools that support spatially related decision-making, which stand to benefit from the development of SDIs. SDSS are geocomputational systems developed to access and utilise domain (discipline-focussed) knowledge bases to support decision-making by the generation of alternative (weighted) solution scenarios, and spatial representations of these through maps and cartographic tools. In particular SDSS offer facilities to pool information in knowledge bases, so that benefit may be derived from sharing spatial and contextual information among stakeholders of different disciplines through geocomputational and decision-modelling support.

SDIs and SDSS have emerged independently with the common objective of optimising the utilisation of available spatial data to support spatial decision-making. Whilst the roles SDSS and SDI development play in the spatial data industry are arguably at very different scales in terms of spatial problem solving, advantage can be gained from the development of each toward a greater ability to incorporate spatial data into decision making processes. Facilitating the integration of institutional and technical initiatives by SDI is one approach to the achievement of this objective and will result in SDI achieving greater functionality supporting spatial data utilisation and sharing. A wider audience of spatial data users and producers may consequently benefit from the improved functionality of SDI, which in turn improves the opportunity for effective use of SDSS to support decision-making.

1.1 Spatial Data Infrastructures

Spatial Data Infrastructure (SDI) initiatives around the world have developed in response to the need for cooperation between users and producers of spatial data to facilitate the means of establishing an environment where spatial data sharing and development can proceed (McLaughlin and Nichols 1992, Coleman and McLaughlin 1998, Rajabifard *et al.* 1999, 2000). Discussions about the concept of SDI began in the United States in the late 1980s (Tosta 1999), primarily in the academic community, although government agencies had begun to use the term by 1989 (National Research Council 1993).

Researchers and various national government agencies have described the nature of SDI in definitions produced in various contexts (McLaughlin and Nichols 1992, European Commission 1995, ANZLIC 1996, McKee 1996, GSDI 1999). Although stakeholders from different disciplines understand SDI differently, it is commonly recognised that an SDI can include core components of policy, fundamental datasets, technical standards, access networks and people, and adopt different design and implementation processes (Coleman and McLaughlin 1998, Phillips *et al.* 1999). The concept has recently been extended to represent SDI as an integrated, multi-levelled hierarchy, formed from inter-connected SDIs at corporate, local, state/provincial, national, regional (multi-national) and global levels (Chan and Williamson 1999, Rajabifard *et al.* 1999, 2000).

The principal objective for developing SDI for any political/administrative level, as highlighted by Rajabifard *et al.* (1999), is to achieve better outcomes for the level through improved economic, social and environmental decision–making. The role of SDI is to provide an environment in which all stakeholders, both users and producers, of spatial information can cooperate with each other in a cost-efficient and cost-effective way to better achieve organisational goals. SDIs have the potential to increase business opportunities for the geographic information industry, and promote widespread use of the available spatial data sets, which are essential to optimise spatial technology support for decision-making processes.

1.2 Spatial Decision Support Systems (SDSS)

The spatial technologies to support decision-making available today are still evolving and have been characterised in recent years by rapid technological and scientific developments (Goodchild and Longley 1991, Cartright 1993, Burrough and McDonnell 1998, NCGIA 2000, Power 2000). There is particularly an increasing emphasis on modelling as a means of optimising spatial information and decision-solution scenarios (Gore 1998). The late 1990s have seen this trend toward modelling decision scenarios generalised for a variety of tools of different levels of expertise and useability (Savolainen 1999, Feeney *et al.* 2000). However, SDSS are distinguished by their ability to represent spatial data, usually by the integration of GIS (Crossland *et al.* 1992, Copas 1993).

SDSS may be represented by very low-end decision-aid tools with minimal functionality, restricted datasets, minimal complexity and at the same time minimal process transparency (Feeney *et al.* 2000) through to high end expert systems employing multi-criteria analysis, agent technology and model interoperability (El Swaify and Yakowitz 1998, Savolainen 1999). Higher end SDSS require the technical capabilities of database management, model-based software/management, and dialogue generation software to achieve data functionality, logical data structures, model creating capabilities, maintain existing models, interrelate models and access integrated models (Crossland *et al.* 1992, Rowe and Davis 1996, Salvolainen 1999).

Broad utilisation of SDSS for complex spatial decision-making involves incorporation of appropriate spatial data into decision-making processes: a double-sided process requiring access to spatial data, as well as access to the supported decision process by decision makers. The first, access to spatial data, presents issues of data cataloguing and discovery, maintenance, custodianship, access networks, exchange standards, data scales, data quality and metadata. Many of these have been identified and are being targeted by institutional initiatives to facilitate utilisation and sharing of spatial data through policies to increase interoperability and the ability to document data useability. These institutional policies were once driven by the technologies developed for spatial data handling, manipulation and management. However, the second side to supported decision-making process is now institutionally (and socially) driven: increased awareness of methods for integrating technical and institutional initiatives by means of SDI has created the demand for technologies to be integrated into support for complex decision-making.

As a result, many SDSS have been developed around existing datasets to 'best address' complex decisions about environmental and resource management, to site two examples. Where SDSS have over the last 2 decades overcome the technological barriers of independent development of computer analytical and visualisation capabilities, to facilitate complex multi-criteria modelling of solution spaces, what now constrains broader use and application of emerging models and tools are user access and skills, as well as access to, quality and completeness of spatial data to support the decision making process. These problems suffer from the lack of integration of the institutional initiatives supporting spatial data networks, use and exchange, with technical initiatives developed to actually process and shape the data. Whilst SDI has raised awareness about how these may benefit spatial data utilisation the process of achieving the optimisation of spatial data use, through technical and institutional integration, is still in its early stages

1.3 Optimising Spatial Data Utilisation

Optimisation of spatial data utilisation requires a much greater understanding be gained of what that data represents, its potential management, technological uses and derivations. Metadata is a central aspect of this. Metadata is the means by which data informs about itself, is able to be stored, managed, partake in transactions, models and audit trails *etc*. (Jacobi and Lind 1997, Ramroop and Pascoe 1999).

Metadata is thus a key link between integrating the technical and institutional spatial data initiatives in any SDI. Metadata is used for data management, by applications and more recently has been used for data processes in the development of meta-object facilities (Ramroop and Pascoe 1999). It is thus very often the link between data, applications, users and the way the aforementioned interact with the policies and protocols of SDI. Considering SDI influences the spatial data interactions of data users through producers, metadata is central to building the link between a conceptual level of understanding of the data for all potential users as well as the technical means of developing and communicating data useability.

The spatial data community participate in different levels of decision-making, from strategic, through tactical and operational, in the management and utlisation of spatial data. The influence of SDI through decision-making frameworks therefore varies. SDI functioning at a very strategic level influences decision-making through the formulation of policy, technical standards, access networks and channels of communication to facilitate spatial data sharing between people. At tactical and operational levels the principles behind the SDI concept must translate to better data management to achieve business and organisational objectives effectively for decision makers. For spatial decision making such data management translates to increased capacity for resource discovery, interoperability, access to data lineage, spatial process and quality documentation.

Metadata has involvement at all of the decision-making levels through recording of custodianship, scale, data currency, quality, licensing, enabling cataloguing and discovery, informing of data usability, enabling data transactions, as well as facilitating data analysis, process recording and auditing. For strategic decision-making metadata enables understanding of the management practices and procedures in place for spatial data that will influence the formation of industry partnerships for data exchange. Metadata also influences strategic decision making about the introduction and implementation of new data standards; influences decisions made about procedures of operation; and enables recognition of gaps in data resources essential to achieving or strengthening business processes. Tactical decision-making relies on metadata for the planning, utilisation, maintenance and proceduralisation of all data-related activities from who is carrying them out, how, to what quality and standards and for use with what applications. Operational decision-making relies on metadata about specific datasets to be available, current, accurate and informative so that data may be processed, catalogued, and effectively used with appropriate applications.

Metadata is thus a central part of decision-making frameworks and spatial data utilisation within the spatial data community. Figure 1 demonstrates the crossover the influence of metadata has in enabling SDI integration of institutional and technical initiatives to support spatial decision making toward different objectives. SDI influences decision-making at all levels, but is particularly reliant on metadata facilitating the benefits of knowledge about spatial data and applications to support strategic decision-making. The corollary of this is that metadata enables SDI to facilitate strategic decision-making benefiting greater utilisation of spatial data and applications throughout the varied decision-making levels. Particularly by increasing the contact and interface of the different levels of decision-making, metadata opens channels for optimising the use of spatial data. Optimising the use of spatial data occurs through developing context for decision-making, by increasing the transparency of spatial data policies, standards and access networks for use of data and applications. This enables SDI to functionally provide decision makers with infrastructure by which they may access the requisite data to support decision-making.

Therefore, metadata development forms a very important part of addressing more effective incorporation of spatial data into decision-making processes. However, metadata is an area of underdevelopment in spatial data documentation, management, custodianship and user understanding. Tosta (1999) believes the value of metadata to the evolving SDI concept will continue to grow and will become of increasing emphasis in data maintenance, despite the complexity of current metadata standards, the expense of their development and implementation. In addition, as more data are Internet-served, the requirements that these data be searchable in a variety of ways will increase. In this way metadata is evolving to be of increasing importance to SDI supporting spatial data transactions, business activity, spatial process management and organisation within the spatial data community (Tosta 1999). Metadata is key to increasing the functionality of SDI by integrating technical and institutional initiatives for the optimal use of spatial data.

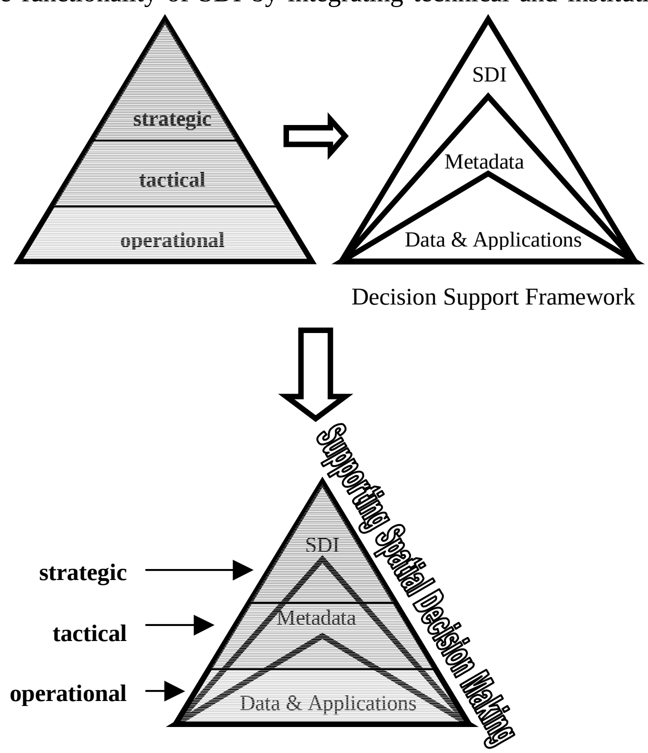

Figure 1:*The Decision Making and Decision Support Frameworks for Incorporating Spatial Data into decision-making*

Metadata was introduced as a concept to help users describe and thus better cope with management of the data. There are a variety of metadata standards developed for spatial data (for example ANZLIC, Dublin Core, CSDGM) (Jacobi and Lind 1997, Ramroop and Pascoe 1999) and activities to develop standards for cross-disciplinary metadata are already underway (SCHEMAS 2000). The technical limitations of these approaches to the development and utilisation of metadata to date have been the ability to adequately describe the data being used, and satisfy the technologies by which the data are used (Jacobi and Lind 1997). This impedes optimal use of the data and often, optimal return from the data.

The need for research on issues like metadata development at the interface between the technological and institutional components of SDIs has been supported by ongoing emphasis in the literature of the role of people, specifically users, in our examinations of the purpose, benefits and operations of SDIs, including the technological components (see for example Pinto and Onsrud 1995, Keen 1987, Rajabifard *et al.* 1999). User understanding, application and management of metadata thus have a significant impact on the capacity of spatial data utilisation facilitated by SDIs and data usability to support semi-structured decision-making and the applications of SDSS.

Establishing what flexibility in standards is required and where is essential for adopting expandable, adaptable, but useful 'standards' and active frameworks for data and metadata development. This understanding is essential to actually move closer to achieving a 'spatial data paradigm' (Openshaw 1991) where information exchange and access really are facilitated by SDIs and enhance the use of SDSS for users seeking support in spatial decision-making.

2.0 RESEARCH PROCEDURE

Integrating SDSS use and SDI initiatives toward the provision of an optimal environment for spatial decision 5making, needs to be facilitated by a methodological framework addressing disparity between policies for spatial data access and management and the use of SDSS. Therefore, the hypothesis the research aims to address is:

Increasing the functionality of Spatial Data Infrastructures (SDI) to support utilisation of spatial data for decision making can be facilitated by developing methods for the integration of Spatial Decision Support Systems (SDSS)

The objectives of the research, to investigate this hypothesis and develop a methodological framework for how SDIs may be designed to enhance the capacity for utilisation of spatial data for decision making, will be to:

1. Establish the current relationships between SDIs and SDSS;
2. Develop criteria to measure how SDIs and SDSS facilitate utilisation of spatial data for decision making, including discovery of data and understanding of data usability, metadata development;
3. Develop case studies of the roles of SDIs and SDSS supporting utilisation of spatial data by decision making groups, against which to measure the evaluation criteria;
4. Develop conceptual models of the data flows between SDIs, SDSS and decision makers to understand and represent differential capacity for the utlisation of spatial data for decision making;
5. Outline and evaluate methods of enhancing the capacity for utilisation of spatial data for decision making through the integration of SDSS by SDI initiatives;
6. Develop a methodological Framework for SDIs to achieve integration of SDSS to enhance the capacity for utilisation of spatial data for decision making.

This research aims to define ways SDI initiatives may more effectively facilitate incorporation of spatial data into decision making. It is postulated that the effectiveness of SDI to support decision-making can be enhanced by the integration of SDSS. User access to and management of spatial data and related information resources, and the means to achieve these facilitated by SDIs, is an aspect of the research pivotal to understanding and effecting integration between SDI initiatives and the use of SDSS to support decision making environments. Case studies of areas where initiatives aiming to achieve similar objectives will be carried out to identify the contrasts and similarities of contemporary approaches and how SDI design may adapt to evolving or as yet unengaged user needs.

The importance of SDI uptake lies in the development of functionality facilitating an interactive user environment for spatial data access. This requires devolution of the institutional and technical components behind the SDI concept to the social system in which it must be activated and for key bridges between the concepts and user operation to be developed. Understanding, representation and management of the data will be a necessary practical link in this process, engendering metadata an important aspect of any model of evolving SDIs. The latter will be investigated through developing conceptual models of the data flows linking SDSS and SDIs and decision makers, to evaluate the current and potential methods for managing spatial data resources to support decision-making. The models will enable the design of a methodological framework for SDIs to effect integration of SDSS to enhance the capacity for utilisation of spatial data for decision-making.

2.1 Methodology Review

Although the technical ability to readily share geographic information might be accessible or achievable, there are still impediments to organisation and infrastructure facilitation incorporating many of the emerging Geographical Information (GI) technologies. Coleman and McLaughlin (1998) found some of the most neglected information research in the development of SDIs fell in the areas interfacing technology and infrastructure – the intersections of policies, standards, people, data and the integration of technologies themselves. Pinto and Onsrud (1995) believe the relationship between GI technologies, information sharing, systems satisfaction, effectiveness, efficiency and decision making has received little attention to date. This has important implications about the way that GI technologies and the support of SDIs are able to effectively incorporate spatial data into spatial decision making. The research frequently points to the increasing importance of this problem (Pinto and Onsrud 1995, Coleman and McLaughlin 1998, Gittings 1999, Tosta 1999).

However, methodologies to research problems related to the field are somewhat disparate and still support systems and infrastructure research in varying degrees of isolation. Alternatively, focus may be taxonomies for describing the process of data sharing, rather than designing frameworks for integrating GI technologies and complementary infrastructure initiatives. Of particular interest to the research at hand is the variety of established methods that may structure a methodological approach for developing a framework to integrate SDSS by SDIs. To investigate methodological frameworks for integrating technologies and emphasising the role of the user in systems design and data flows, the divergence in the broad area of information systems research was reviewed in preliminary literature reviews (Gory and Scott Morton 1971, Lucas 1973, Savolainen 1994, 1999). The differences in approaches adopted by the semi-independent fields of emerging research in database management, and the differing forms of decision support systems was also required (Mason and Mitroff 1973, Ives *et al.* 1980, Nolan and Wetherbe 1980, Keen 1987, Savolainen 1999, Power 2000).

2.2 Research Design and Methodology

The framework of Savolainen (1999) has been derived from linguistic and systems theories, to employ what are, in methodological engineering, techniques of literal and meta-model development. Modelers have argued for years about the best approach for developing data and data flow models, until recently considering literal and meta-level models as exclusive alternatives (Moriarty 1997). Literal models are developed around the data flows, process information and business rules exactly as provided, essential in validating those existing within the framework of an information system (Moriarty 1997). Meta-level models look behind the data flows, process information and business rules in an attempt to extract any hidden patterns or gaps that may exist. Meta-level models are extremely adaptable to an evolving organisation or information system environment, but do not depict the current processes very well, especially in isolation (Moriarty 1997, Savolainen 1999).

Both the meta-level and literal models are essential to understanding, managing and adapting data flows, process information and business rules, and in the case of Savolainen (1999) information systems designs, especially those which address user access and needs. The literal serves as a guide in developing the operational systems that must enforce the information system processes, not to mention providing an operational framework to evaluate current systems and information processing. The meta-level model provides a framework for initiatives, such as the data cataloguing, warehousing, metadata development, standards and policies, which provide management with an integrated view of the organisation’s data and are able to emphasise disparate data and ineffective information flows (Moriarty 1997). The latter in particular facilitates the opportunity to examine the intersection of SDI initiatives in terms of standards, polices, access networks linking people and data and the link to information activities of SDSS.

Meta-level modelling is particularly important in examining the intersection of data, data flows and infrastructure in a systems environment. This is highlighted by the partial metamodel breakdown provided by Tolvanen (2000) in Figure 2 below. Tolvanen (2000) emphasises that metamodels address partial aspects of a method enabling the making of methods explicit, enabling the systemisation and formalisation of method knowledge, as well as touching on metadata and process metamodels. Breaking the flow and utilisation of data down into literal and meta-level models therefore provides the basis for examining key elements of existing and optimal methods to enable the building of a methodological framework.

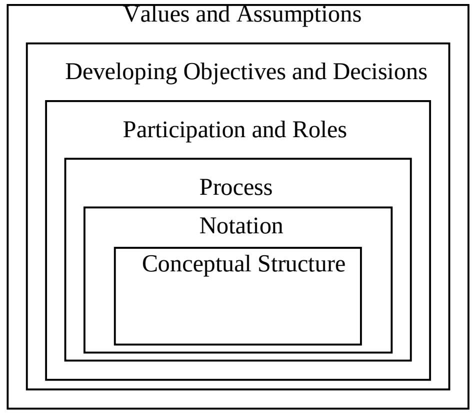

Figure 2: *Representing the Breakdown of a Metamodelling Approach (an example from Tolvanen 2000).*

Based on the existing research and the multidisciplinary nature of the research problem this project will adopt the use of literal and meta-level models to evaluate methods for the integration of SDSS by SDIs. The models will be developed from a case study methodology. Case study evaluation criteria will contribute to the development of literal and meta-level models of the SDSS and SDI data flow systems, particularly the metadata systems. Evaluation of the literal models will provide construction of a framework and understanding of the data management, flow and processing of current SDI and SDSS systems. This will provide the means for meta-level modelling of these and comparative analysis against SDI and SDSS integration in other states and overseas, for model refinement and framework evaluation.

To build a detailed model of methods for integrating SDSS into SDIs, case studies will be carried out throughout Australia, with reference to the variations between State SDI initiatives, the regional and Local complements, as well as the over-arching structure of the Australian SDI. SDIs differ significantly in the utilisiation of partnership programs, the perceived role of capacity building in users, the processes of metadata development, the integration of decision support technologies, the development of SDI hierarchies, and their principle objectives. These are just a few factors that shape how SDI functionality supports utilisation of spatial data for decision making.

2.3 Case Study Methodology

The degree of integration of SDI initiatives and SDSS will be investigated by means of pursuing a case study methodology to gather data. This approach is imperative to being able to

- achieve triangulation between multiple sources of evidence (Yin 1994, Tashakkori and Teddlie 1998),
- carry out targeted field work focusing on the evidence deemed relevant,
- emulate logical positivism in developing alternative models of data and metadata processing for SDIs and SDSS (based on literal circumstances, as well as meta-level models of data flows), and
- collecting external evidence bearing on those models in order to design and refine a framework that may facilitate better integration between SDIs and SDSS use.

This research will require both qualitative and quantitative research approaches. These will enlist industry visits, structured and semi-structured interviews, investigating data and systems processing, handling sample data, evaluating standards and policies that influence data and metadata, and attending stakeholder forums and workshops. Comparative surveys of SDI initiatives pursuing policies for technological integration in Australia and overseas will also be conducted.

2.3.1 A Catchment Decision Making Focus

The case studies of SDI and SDSS will focus on natural resource management issues, dealt with generally through catchment management initiatives. The rationale for the selection of a specific research theme is to enable the establishment of a comparative framework for the case studies as well as enabling contrast to be drawn between the difference in state approaches to integrating SDI initiatives and SDSS use.

Numerous natural resource management decision support tools have been developed aimed at catchment decision-making, including CMA DSS, Facilitator, NRM Tools, CHRRUPP (see Itami *et al.* 2000, Walker *et al.* 1997, 1998 as well as McAllister 2000, Rampant 2000). There are also some innovative SDI models emerging, within catchments and/or for natural resource planning, which harness the tools of partnerships, spatial data sharing, and capacity building to develop access networks to spatial data to support regional decision making about natural resource, and related issues. The CRIC (Community Research Information Centre) model of Northern Queensland (Walker *et al.* 1997, 1998, Bischof 2000) and SCRIPT (South Coast Resource Information Planning Team) model of Western Australia, are two currently being road tested. The latter have been precipitated by the very dispersed settlement of these states (e.g. in Queensland 95% of the state lives in the South East, the other 5% are dispersed across the rest of the state). However, Queensland and Western Australia are still faced by the pressing need to be able to promote an information-based approach to decision making about natural resource management, by users, and facilitate models of SDI that will enable access to such information, as well as appropriate technologies to support decision-making.

In Australia progress towards catchment planning has been made at an institutional and community level. Queensland, New South Wales and Victoria have created formal structures for administering catchment management, which have been augmented by different community initiatives. Queensland, inparticular, has experienced the development of a number of community-initiated information infrastructure initiatives, which with backing from private and public sector have resulted in the integration of decision-supporting GI technologies and the development of SDIs. Victoria, on the other hand, has benefited from proactive government investments in establishing State SDI that links projects from the local spatial data community through to national initiatives affecting the state. Leadership from the Victorian Government in developing prototype decision-supporting technologies, and industry partnerships, has generated community involvement and support by example and experience of the initiatives. Victoria and Tasmania have also developed significant planning information tools facilitating access to much government data via the Internet.

Integrated catchment management presumes a holistic approach to decision making and requires scientific knowledge (able to be recast within the socio-political decision making framework), data available on natural and social conditions, local experience and the creativity and vision of a community (Walker *et al*. 1997, Itami *et al.* 2000). In order to more effectively integrate scientific understanding into the decision making process, researchers are increasingly required to understand the process itself (Walker *et al* 1997), as well as consider the multiple, economic, social, ecological, political and technical dimensions of land management. Thus a comprehensive, integrated approach to decision making for catchment management must help people structure these complex problems in a framework that takes advantage of the best scientific knowledge, where it exits, and capitalises on the knowledge and experience of local experts and the community, often via the means of decision support systems.

The role of SDI in providing an environment for the exchange of spatial data influences the availability, access and interoperability of data that may support catchment decision making frameworks, and can thus at times be as important as the tools available to structure the decision making. The degree of integration of SDI initiatives and decision support systems use can implicate the effectiveness achieved between the two towards a supported decision environment. The latter is especially true in the context of the governments' increasing preference for negotiated and consensual management by multiple stakeholders and decision makers for natural resource management (exemplified by Property Management Planning, LandCare and Integrated Catchment Management programs) (Brown 1995 in Walker *et al*. 1997, Walker 1997, AFFA 1999, 2000).

Victoria and Queensland are two Australian states that have made commitments to support catchment management decision making through the development of SDSS and SDIs to optimise the research, data and analytical tools available to enhance the decision making process. They provide a starting point for case study development, the background and nature of which is described for each state below, to reflect the scope of the research to be sustained

3.0 SUMMARY

This research aims to investigate the accuracy of the current perception that SDI functionality can be increased to support the utlilisation of spatial data to support decision making, especially through the integration of SDSS. Current SDIs achieve less than their potential in supporting spatial decision making environments due to a lack of integration of SDSS applications and the policies and networks framing the applications within SDI. In many respects SDIs and SDSS continue to develop largely independently. Mutual benefit stands to be derived by SDIs having the capacity to facilitate exchange of spatial data resources between stakeholders wishing to use such resources to support complex spatial decision making with SDSS. Extending the capability of SDIs to facilitate the understanding and application of spatial data resources by community stakeholders to support decision making achieves opportunities for the spatial data community to realise improved spatial resource management, discovery, access and a greater reliability on being able to derive the fitness of data to its proposed use. Moreover, it extends the opportunity for the inclusion of new forms of data and facilitates the integration of other spatial technologies, not to mention the better integration of existing technologies, and existing spatial data resources, into the traffic of the spatial data community through the establishment of methodological frameworks for SDIs to integrate SDSS, and the flow on effect this may have for other decision supporting technologies.

ACKNOWLEDGEMENTS

The authors wish to gratefully acknowledge the support of Land Victoria (LV) of The Victorian Government, the Australian Research Council (ARC - Grant Number C49930403) and the University of Melbourne (MU) Spatial Data Infrastructure Research Group http://www.geom.unimelb.edu.au/research/SDI_research/, in the preparation of this paper and the associated research. However, the views expressed in the paper are those of the authors and do not necessarily reflect the views of MU, LV or ARC

REFERENCES

AFFA (1999) Managing Natural Resources in Australia for a Sustainable Future. A discussion Paper for developing a national policy. December 1999. AFFA job no. 950124

AFFA (2000) Steering Committee Report to Australian Governments on the public response to Managing Natural Resources in Rural Australia for a Sustainable Future: A discussion Paper for developing a national policy. July 2000. AFFA job no. 950155

ANZLIC (1996) National spatial data infrastructure for Australia and New Zealand. Commonwealth of Australia. Accessed 11 January, 1999. <http://www.anzlic.org.au/anzdiscu.htm>

Bishof R. (2000) Information Resource Centres – supporting community action AND Regional Planning Information Systems. Workshop Descriptions. AURISA 2000 Registration Brochure.

Brown V.A. (1995) Turning the Tide: Integrated Local Area Management for Australia's Coastal Zone. DEST, Canberra.

Burrough P.A. (1986) *Principles of Geographical Information Systems for Land Resources Assessment*. Monographs on Soil and Resources Survey No 12. Clarendon Press, Oxford. 193p [Expert Systems for Geographical Information Systems: 143-145]

Burrough P.A. and R.A. McDonnell (1998) *Principles of Geographical Information Systems* 2nd edition . Oxford University Press.

Cartright T.J. (1993) Geographic Information Technology as an Appropriate Technology for Development. In Masser, I and Onsrud, H J (eds) *Diffusion and Use of Geographic information Technologies*. Kluwer Academic Publishers, Netherlands. P261-274

Chan T.O. and I.P. Williamson (1999) Spatial Data Infrastructure Management: lessons from corporate GIS development. *Proceedings of AURISA '99, November 1999, Blue Mountains, NSW*, AURISA 99: CD-ROM <http://www.geom.unimelb.edu.au/research/publications/IPW/ipw_paper31.html>

Coleman D.J. and J.D. McLaughlin (1998) Defining Global Geospatial Data Infrastructure (GGDI): components, stakeholders and interfaces. *Geomatica* 52: 129-144

Copas C.V. (1993) Spatial Information Systems for Decision Support. In Medyckyj-Scott, D and Hearnshaw, H M (eds) *Human Factors in Geographical Information Systems*. Belhaven Press, London. Pp158-167

Crossland M.D., B.E. Wynne and W.C. Perkins (1992) Spatial Decision Support Systems: An Overview of Technology and a test of Efficacy. *Presented at the Conference of the International Society for Decision Support Systems*, Ulm, Germany. June 1992

El-Swaify S. A. and D.S. Yakowitz (1998) Multiple Objective Decision Making for Land, Water, and Environmental Management. *Proceedings of the First International Conference on Multiple Objective Decision Support Systems (MODSS) for Land, Water, and Environmental Management: Concepts, Approaches and Applications*, Honolulu, Hawaii 1996. Lewis Publishers, US.

European Commission (1995) GI2000-Towards a European Geographic Information Infrastructure (EGII)-A discussion document for consultation with the European GI community. European Commission. Accessed 14 February, 1999. <http://tempus1.utc.sk/gis/txts/gi2000xz.htm>

Feeney M., F. Escobar and I. Williamson (2000) Future Application of GIS: Depth versus Breadth - The Case of the Land Use Profiler. To be presented at AURISA 2000 Conference, 20-24 November, Coolum, Queensland.

Gittings B. (1999) *Integrating Information Infrastructures with GI Technology*. Innovations in GIS 6. Taylor and Francis, London.270p.

Goodchild M.F. and Longley (1991) The Future of GIS and Spatial Analysis. In Maguire D.J., M.F. Goodchild and D.W. Rhind (eds) *Geographical Information Systems Principles and Application*, New York, Longman Scientific and Technical, John Wiley and Sons, vol 2, 40: 567-581

Gore A. (1998) The digital earth: understanding our planet in the 21st century. *The Australian Surveyor, 43(2), 89-91.*

Gorry G.A. and M.S. Scott Morton (1971) A Framework for Management Information Systems. *Sloane Management Review* 13(1): 55-70

GSDI (1999) GSDI home page. Accessed 13 February, 1999. < http://www.gsdi.org/index.html>

Itami R.M., G. MacLaren and K. Hirst (2000) Integrating the Analytical Hierarchy Process with GIS to Capture Expert Knowledge for Land Capability Assessment. *4th International Conference on Integrating GIS and Environmental Modeling (GIS/EM4): Problems, Prospects and Research Needs*. Banff, Alberta, Canada. 2- 8 September, 2000.

Ives B., J.S. Hamilton and G.B. Davis (1980) A Framework for Research in Computer-Based Management Information Systems. *Management Science* 26(9): 910-934.

Jacobi O. and M. Lind (1997) Metadata: From European Standard to User Service. *Proceedings of the Third Joint European Conference and Exhibition on Geographical Information*, Vienna, Austria. 1997.

Keen P.G.W. (1987) Decision Support Systems: The Next Decade. *Decision Support Systems* 3(3): 253-265.

Lucas H.C. Jr (1973) A Description Model of Information Systems in the Context of the Organization. *Data Base* : 27-39.

Masser I. and H.J. Onsrud (eds) (1993) *Diffusion and Use of Geographic information Technologies*. Kluwer Academic Publishers, Netherlands. 349p.

Mason O. and I. Mitroff (1973) A Program for Research on Management Information Systems. *Management Science* 19(5).

Mc Allister A. (2000) GIS Tools and Techniques for Successful Support of Land and Water Management. Sharing GI Technology, NRE GIS Conference.15 June, 2000.

McKee L. (1996) Building the GSDI—discussion paper for the September 1996 Emerging Global Spatial Data Infrastructure Conference. *Proceedings of the 1996 Conference on Emerging Global Spatial Data Infrastructure*, Konigswinter, Bundesrepublik, Deutschland (Germany). *September, 1996.* European Umbrella Organization for Geographical Information (EUROGI): 19 Pp.

McLaughlin J.D. and S.E. Nichols (1992) Building a national spatial data infrastructure. *Computing Canada* 6th January: 24.

Moriarty T. (1997) Dueling Models. *DAMA International Metadata Symposium and Conference.* 17-20 March, 1997. Dallas, Texas <http://www.tticom.metadata97/sessions.html>

National Research Council (1993) Toward a Coordinated National Spatial Data Infrastructure for the Nation. National Academic Press, Washington, D.C.

NCGIA (2000) Geographic Information Science: Emerging Issues in a cross-disciplinary research domain. National Centre for Geographic Information Analysis, USA. Accessed 11 May, 2000. <http://www.geog.buffalo.edu/ncgia/GIScienceReport.html>

Nolan R. and J. Wetherbe (1980) Toward a Comprehensive Framework for MIS Research. *MIS Quarterly* 4(2): 1-19.

Openshaw S. (1998) Toward a more computationally minded scientific human geography. *Environment and Planning A* 30:317-332.

Openshaw S. (1993) Over twenty years of data handling and computing in Environment and Planning. *Environment and Planning A*, Anniversary Issue: 69-78.

Openshaw S. (1991) A view on the GIS crisi in geography, or using GIS to put Humpty Dumpty back together again. *Environment and Planning A*, 1991 23: 621-628.

Phillips A.H. (1998) A Metadata Management System for Web Based SDIs. Unpublished Dissertation, Master of Geomatic Science, University of Melbourne, Australia.

Phillips A. H., I.P. Williamson and C. Ezibalike (1999) Spatial Data Infrastructure Concepts. *The Australian Surveyor* 44(1): 20-28.

Pinto J.K. and H.J. Onsrud (1995) Sharing Geographic Information Across Organizational Boundaries: a Research Framework. In Onsrud H.J. and G. Rushton (eds) *Sharing Geographic Information*. Centre for Urban Policy Research, New Brunswick, NJ. Ch 3: 44-64.

Power D.J. (2000) Web-based and Model-driven Decision Support Systems: Concepts and Issues. *AMCIS 2000, Americas Conference on Information Systems, Long Beach, California*. August 10-13, 2000.

Rajabifard A., T.O. Chan and I.P. Williamson (1999) The Nature of Regional Spatial Data Infrastructures. *Proceedings of AURISA '99, November 1999, Blue Mountains, NSW*, AURISA 99: CD-ROM <http://www.geom.unimelb.edu.au/research/publications/IPW/ipw_paper32.pdf.pdf>

Rajabifard A., I.P. Williamson, P. Holland and G. Johnstone (2000) From Local to Global SDI initiatives: a pyramid building blocks. *Proceedings of the 4th GSDI Conference*, Cape Town, South Africa. <http://www.geom.unimelb.edu.au/research/publications/IPW/ipw_paper41.pdf>

Rampant P. (2000) Enhanced Resource Assessment for Regional Development. Sharing GI Technology, NRE GIS Conference. 15 June, 2000.

Ramroop S. and R. Pascoe (1999) Processing of spatial metadata queries within federated GISs. *Proceedings of the 11th Annual Colloquium of the Spatial Information Research Centre*, University of Otago, Dunedin, New Zealand. 13-15 December, 1999.

Rowe A.J. and S.A. Davis (1996) *Intelligent Information Systems. Meeting the Challenge of the Knowledge Era.* Quorum Books, Westport CT.

Savolainen V. (1999) *Perspectives of Information Systems.* Springer-Verlag New York. 271p.

Savolainen V. (1994) Reference Frameworks for Information Systems and Development: an Evaluation. *Informatics and Control* 3(4): 285-307.

SCHEMAS (2000) Forum for Metadata Shema Implementers. Last Updated 18 Aug 2000.Accessed 20 August, 2000. <http://www.schemas-forum.org/ >

Tashakkori A. and C. Teddlie (1998) *Mixed Methodology*. *Combining Qualitative and Quantitative Approaches.* Applied Scial Research Methods Series. Volume 46. Sage Publications, CA.

Tolvanen J.P. (2000) Defining metamodeling and metamodels. Created 20 January, 2000. Accessed 25 August, 2000. <http://www.cs.jyu.fi/~jpt/ME2000/Me06>

Tosta N. (1999) NSDI was Supposed to be a Verb. In Gittings B. (ed.) *Integrating Information Infrastructures with GI Technology*. Innovations in GIS 6. Taylor and Francis, London. Chapter 2: 3-24.

UCGIS (2000) Spatial Analysis in a GIS environment. University Consortium of Geographic Information Systems, USA. Accessed 11 May, 2000. <http://www.ucgis.org/research_white/anal.html>

Walker D.H., S.G. Cowell and A.K.L. Johnson (1998) Integrating R&D into Decision-Making for Natural Resource Management at a Regional Scale. Association for Farming Systems Research and Extension Conference.1998.

Walker D.H., A.K.L. Johnson and J.A. Bellamy (1997) Integrating R&D into decision-making for natural resource management in coastal northern Australia. *Proceedings of The Great Barrier Reef, Science, Use and Management National Conference*. 25-29 November, 1996. James Cook University of North Queensland, Townsville**.** 2:122-127.

Yin R.K. (1994) *Case Study Research: Design and Methods. Second Addition*. Applied Social Research Methods Series, Volume hyam46 5. Sage Publications Inc., Thousand Oaks, CA.