A Framework for Comparing Spatial Data Infrastructures: An Australian–Swiss Case Study

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ABSTRACT

Spatial data infrastructures (SDIs) facilitate data sharing and rely on effective management of data, metadata, and Web services. A framework for evaluating SDI initiatives has been developed, and the national SDIs of Australia and Switzerland are compared on the basis of these criteria.

INTRODUCTION

Many countries are developing spatial data infrastructures (SDIs) to better manage and utilize their spatial data by taking a perspective that starts at the local level and proceeds through state, national, and regional levels to the global level. The emergence of different SDIs at and between these levels has brought attention to the SDI hierarchy (figure 1).

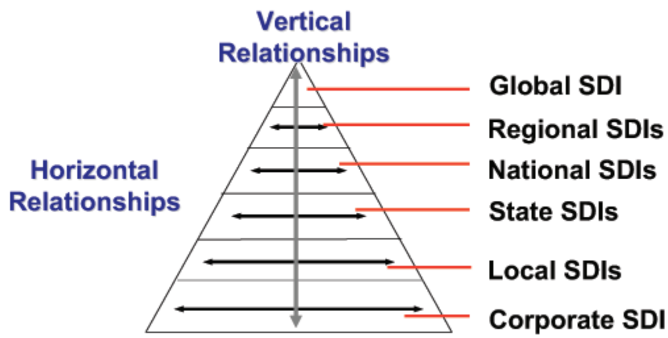

Figure 1. Hierarchy of SDI levels.
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Since SDI development, maintenance, and operation require huge investments, indicators for judging SDI performance and determining cost/benefit ratios are needed. Stakeholders are interested in monitoring SDI development and impact on the geoinformation market.

Although nearly all of the SDI initiatives use the same (or similar) basic technology and standards, they are hard to compare because of their different legal and organizational backgrounds. Best-practice solutions do not seem to exist because the organizational framework plays an important role in an SDI's success and cannot easily be transferred from one institution or country to another. Clear means of determining the developmental status of an SDI or measuring its impact on geoinformation availability and usage are lacking.

We offer a framework for comparing SDI initiatives using a set of clearly defined indicators, which are as much as possible independent of the organizational backgrounds of the SDIs. We present the results of ongoing research on SDI and metadata management activities in Switzerland and Australia. The framework can simplify characterization of complex enabling platforms and diverse peculiarities and can be used for any national SDI initiative.

We review current SDI monitoring and evaluation methodologies, discuss problems of interoperability on the national level, and apply proposed key indicators to case studies in Switzerland and Australia.

National SDIs. Many governments and organizations have recognized the economic, social, and environmental benefits of SDIs. In 2002 more than half the countries of the world had national SDI initiatives (Borrero et al. 2002; Crompvoerts et al. 2003). By 2005, most countries had national SDI initiatives (Warnest et al. 2005).

SDI development is a long-term process which needs long-term investment and the consideration of organizational and technical issues. The national level is of special significance to SDIs, as this is where juridical, political, and administrative decisions are made for a country and guidance is given for local levels.

As Masser (1999) points out, successful national SDIs are increasingly composed of three elements: identification of core datasets for a wide range of users, development of metadatasets, and a coordination framework to develop the infrastructure.

Although stakeholders understand the need for core spatial data, they are not always aware of the need for adequate metadata. Metadata is needed to describe and label the spatial datasets and thus make them findable for search engines. Furthermore, metadata management, standardization, and modeling are key factors for interoperability within an SDI (Giger et al. 2003).

Web services support the user in processing, accessing, and visualizing data. A worldwide assessment of spatial data clearinghouses found that one of the main factors for success is the inclusion of Web services, and the latest definitions of clearinghouse put more emphasis on the inclusion of services (Crompvoets et al. 2004).

Data, Web services, and metadata are important components of SDIs but not the only ones. Comparative approaches for examining their roles can help identify best practices and targets for improvement (Williamson et al. 2005). SDIs can be compared on the basis of technical, institutional, and conceptual factors.

Comparisons of SDIs. SDI initiatives appeared in several countries many years ago more or less simultaneously, whereas other countries have only just begun planning their SDIs. SDI success can be assessed in different ways. Establishing a general framework and focusing on metadata, spatial data, standards, and Web services makes it easier to find a common denominator. Methods for comparing SDIs on the basis of institutional, political, and financial factors are discussed below.

Rackham and Rhind (1998) compare the UK SDI (National Geospatial Data Framework) with international initiatives by looking at inclusion of the public and private sectors within the NGDF Board, formal political support, and the emphasis on fostering services and facilitating business rather than data.

For comparing the national SDIs of the Netherlands and United States, Kok et al. (in press) created an “organisational maturity matrix” and looked at four organizational “context shaping” components: leadership, vision, communication channels, and self-organization.

Another indicator, SDI readiness, is based on the e-readiness index, which can be defined as the degree to which a country is prepared to participate in the networked world (Group@IMRB et al. 2003), and on factors identified in previous studies (Giff et al. 2002; Kok et al. 2005; Crompvoets et al. 2004). An SDI readiness index uses qualitative factors such as organization, information and data availability, people, access network, and financial resources, as well as decision criteria like political vision-commitment-motivation, institutional leadership, and umbrella legal agreements. Based on a model using fuzzy-compensatory logic, the SDI readiness index compares SDI progress over time within a country. This framework was used to evaluate the Cuban SDI (Delgado Fernandez et al. 2005).

The comparison of national spatial clearinghouses throughout the world by Crompvoets et al. (2004) looked at the year of first implementation, number of data suppliers, monthly number of visitors, number of Web references (Alta Vista and Google), languages used, frequency of Web updates, metadata accessibility, number of datasets, most recently produced dataset, use of maps for searching, registration-only access, and metadata standard.

The land administration framework developed by D. Steudler (2004) combines technical, institutional, and political factors and takes into account the different stakeholders. We extend this framework to SDIs.

Interoperability of SDIs on the national level. To find suitable indicators of SDI success, objectives have to be clearly defined. On the national level, many different organizations (private and public) are involved in producing and maintaining spatial datasets. Often they work as islands or are only partly interconnected. The ideal SDI connects these sources via the Internet and provides users with Web services to find, process, and analyze the spatial data on the spot.

The sharing of datasets using a common platform faces the challenge of interoperability. Figure 2 shows how institutions can connect to a national SDI on the Web. Many data providers manage a great variety of datasets that differ in scale, quality, topic, format, method of acquisition, purpose, and model. This heterogeneity is due partly to missing technical regulations and standardization and partly to institutional obstacles, for example, communication between national agencies or between departments within an agency. Most organizations are simultaneously data providers and users.

Although many problems of access to data will likely decline, problems of data incompatibility or unsuitability for reasons of scale, coverage, or methodology are much less tractable (Bayfield et al. 2005). The exchange of data is possible only with accurate, standardized metadata. Web services of national clearinghouses can search for ASCII-based metadata.

FRAMEWORK FOR COMPARISON OF SDIs

A comparison of national SDIs on the basis of data, metadata, and Web services will lead to a better understanding of best practices and help improve the interoperability of an enabling platform and the integration of data and metadata in common datasets and models (Giger and Najar 2003). Using a case study approach, we compare the national SDIs of Australia and Switzerland, focusing on the important components and related processes especially for metadata and Web services.

The geographic, historic, and political context needs to be understood; objectives need to be clearly defined; the roles of stakeholders and coordinating agencies need to be delineated; and government policy on data sharing (intellectual property rights, privacy issues, and pricing) needs to be take into account (table 1).

Table 2 lists the indicators for the evaluation related to data-metadata, Web services, and standards. Data capture and updating procedures (indicator 1) can be standardized by ISO 9001 certification, for example. Besides standardization, these procedures need to be well-documented.

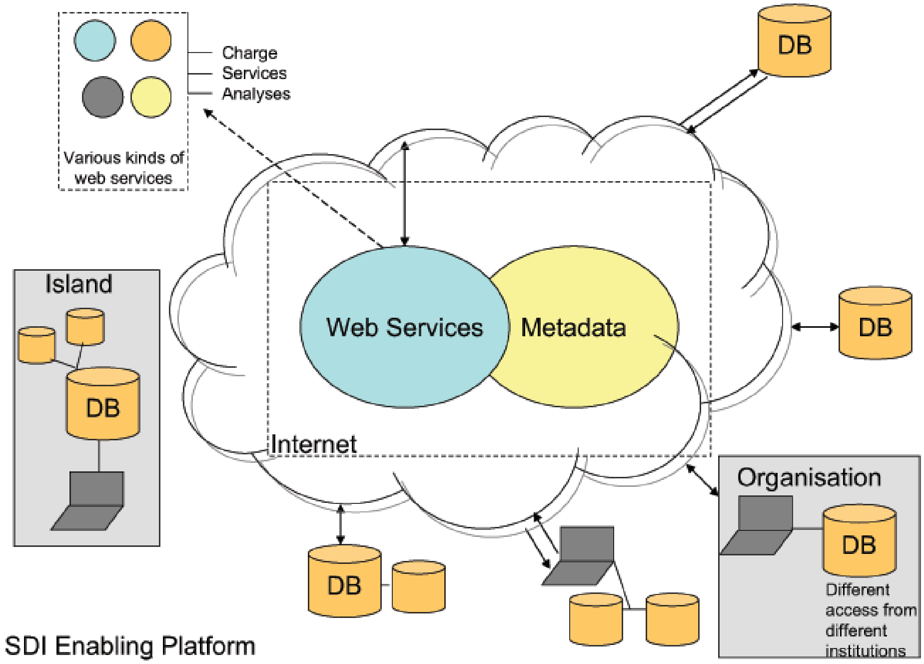

Figure 2. Horizontal interoperability in a national SDI. DB, database.

Characteristic
History Objectives Components Global context Coordinating agency Stakeholders Institutional partnerships Government mandate Data-sharing policy National standards

Table 1. General characteristics of a national SDI.

Component	Indicator	
	Technical	Organizational
Data and metadata	1. Data capture process 2. Definition of core datasets 3. Data format and conceptual model 4. Data management 5. Data quality and accuracy 6. Common modelling language and tools 7. Harmonization of data and metadata	8. Custodianship 9. Data sharing and partnerships agreements 10. Business models 11. Coordinating arrangements
Web services	12. Application profile 13. Clearinghouse and geoportal	14. Clearinghouse organization
Standards	15. Interoperability	16. Organizational arrangements for standardization

Table 2. Indicators for comparing SDIs on the basis of Web services and data management.

Standardization is also important for core datasets (sometimes called reference data) (indicator 2), especially if these are acquired from different organizations. Core datasets are the basic geographic data and should have the highest priority. INSPIRE's Reference Data and Metadata working group has defined three functional requirements for core datasets:

- Provide an unambiguous location for user information
- Enable the merging of data from various sources
- Provide a context for understanding the information

Core datasets need to be clearly defined and well documented.

Integration of data from heterogeneous sources in a network environment requires a neutral format and a conceptual model (indicator 3).

Data management (indicator 4) relies on standardized update cycles and standardized, computer-processable metadata. The infrastructure should be available 24 hours a day, 7 days a week, and updates should be standardized, frequent, and documented. The relationship between data and metadata should also be standardized and documented. SDIs must also effectively manage large databases (e.g., photogrammetric imagery).

Data quality (indicator 5) standards (e.g., update frequency, precision, actuality, reliability) need to be documented for specific applications.

Conceptual models described in a standardized modeling language (e.g., UML) are needed. Tools for importing a model, testing its quality, and checking for mistakes should be provided (indicator 6).

The value of standardized metadata increases if, for example, the metadata is updated simultaneously with the spatial data. Harmonization standards are needed, and data models and metadata models must be coordinated (indicator 7).

Horizontal interoperability can be measured by homogeneous metadata–spatial data sets and catalogues, and it requires that participating organizations have clear guidelines and a focused vision. Indicators 8 to 11 address horizontal interoperability from an organizational point of view.

Well-documented, accessible, checkable, and standardized guidelines for licensing, regulations for custodianship, restrictions on data use and reproduction, and juridical parameters (indicator 8) are needed.

Partners can enter into specific data-sharing agreements or contracts. Clear rules for commercial use, reproduction, and pricing (indicator 9) should be well-documented, accessible, checkable, and standardized.

The basic functioning of an SDI must be secured. This might be possible with a business model that defines a minimal infrastructure that can be financed by a neutral organization (e.g., a government agency) (indicator 10).

Clearly defined and documented coordinating arrangements for participating organizations (indicator 11) ensure continuous workflows and quality control. For example, if a new organization wants to participate in the SDI, it needs to be provided with a set of rules.

In an ideal SDI, horizontal and vertical interoperability will be supported by diverse Web services based on standards set by the Open Geospatial Consortium (ISO/TC211, CEN/TC 287) and the World Wide Web Consortium (3WC) (indicator 12).

A clearinghouse is a specialized, complex Web service for sharing spatial data, and a geoportal is its access point on the Internet (indicator 13). A search engine for finding and retrieving spatial data is a basic function for an SDI.

Data accessibility relies on clearinghouse policies, institutional arrangements, and agreed-upon technical standards (indicator 14). A neutral organization or committee can be officially entrusted to make important decisions for the clearinghouse.

The tranfer of functions accompanying the transfer of data must be standardized (indicator 15). Standardization responsibilities need to be assigned to appropriate organizations (indicator 16).

AUSTRALIA AND SWITZERLAND

Australia and Switzerland are both highly developed countries administered by a federal structure, but their cultural and organizational frameworks differ.

Australian SDI. Australia is the world's sixth largest country in land area and the only country covering an entire continent. It's one of the least populated countries in the world and one of the most urbanized, due to approximately 85 percent of the population residing in urban areas along the eastern and southeastern coastlines. Australia is a Commonwealth comprising six states and two territories.

Australian SDI (ASDI) has been coordinated by Australia and New Zealand Land Information Council (ANZLIC) since 1986, with the aim of making Australia's spatially referenced data, products, and services available and accessible to all.

ANZLIC comprises 10 members representing the Australian government, the New Zealand government, and each of the state and territory governments of Australia. Each member represents a spatial information coordinating structure for whole-of-government within their jurisdiction.

ANZLIC, the Spatial Information Council, the Intergovernmental Committee for Surveying and Mapping (ICSM), and Public Sector Mapping Agencies Australia Ltd. (PSMA) are the key stakeholders of the ASDI.

Swiss SDI. Switzerland is a small but heterogeneous country, with 4 official languages, 26 cantons, and 7 million people. A patchwork of political, legal, and technical issues needs to be harmonized for the national SDI to function effectively.

On the 15th of June 2001, the Swiss Federal Council gave the interdepartmental GIS Coordination Group (COGIS) an official mandate to come up with a plan for a national SDI. This project is embedded in the e-geo.ch initiative, which offers an e-government framework for cooperation among public agencies and the private industry.

The COGIS center is administratively attached to the Swiss Federal Office of Topography (the national mapping agency) but is practically independent.

COMPONENT-BASED COMPARISON OF AUSTRALIAN AND SWISS SDIs

Table 3 summarizes the comparison of the Australian and Swiss SDIs.

Based on the fact that Australia is 183 times larger than Switzerland and contains vast areas of desert, the data capture methods are very different. Both countries have well-established rules and regulations for cadastral data capture, and most of the spatial data is digitalized. The Swiss federal mapping agency is certified by ISO 9001. Therefore, the capturing and updating of the federally acquired cadastral data is standardized through the printing of maps. However, data capture procedures at lower levels of the federal system are not certified, and applications other than cadastral data capture are not well documented or standardized. In Australia on the other hand, national standards are provided by ANZLIC and are based on ISO 9001. They are recommended to the states for adoption. Most states are certified according to ISO 9001 (indicator 1 in table 3).

Australia has defined core datasets organized in five themes: primary reference, administration, national environment, socioeconomic environment, and built environment. Yet, each state in Australia defines its own core datasets. Switzerland is currently inventorying basic spatial data of national interest for upcoming legislation on geoinformation (indicator 2 in table 3).

Data format normally depends on the GIS system used, but Switzerland has defined an additional standardized format, INTERLIS, for data transfer between different GIS systems and models. INTERLIS is mandatory for cadastral data and is becoming more widely used for other data. In both countries the data is stored in a decentralised way, with the custodians of the data also in charge of the metadata and the updating.

In Australia, different jurisdictions have established different solutions, data models, and processes for their digital cadastral data systems. The Intergovernmental Committee on Survey and Mapping provides overall coordination of cadastral standards and promotes data harmonisation (Dalrymple et al. 2003). Switzerland established a national data model for cadastral surveying in the early 1990s, and every canton is obliged to follow it, with the option of extending it to other uses. INTERLIS provides several modeling tools, for example, for checking compliance with the model (www.interlis.ch). In both countries, metadata and spatial data are saved in separate files or databases (indicator 3 in table 3).

The Australian Spatial Data Directory (ASDD) and the Environmental Data Directory (EDD) are the two main national metadata cataloges in Australia. The latter is maintained by the Department of the Environment and Heritage and contains biological survey data, documentation of species, vegetation data, and biological nomenclature. The former is maintained by Geoscience Australia on behalf of ANZLIC and contains 40,000 metadata records on 25 distributed nodes (24 public and one private) covering various topics. The two metadata catalogues are not linked to each other. Update cycles for spatial data are determined at the jurisdictional level (e.g., each state determines its own update cycle for cadastral data).

In Switzerland, Geocat.ch is the main national metadata catalogue. It was launched on the Internet in 2004 and offers metadata in English, German, and French on various topics. Geocat.ch is well documented and is available 24 hours a day, 7 days a week. However, it covers mainly metadata and has no special provisions for large datasets like photogrammetry.

Indicator	Switzerland[a]	Australia[a]
Data and metadata		
Technical		
1. Data capture process		
Well documented	+/-	+/-
Standardized	+/-	+/-
Accessible	+/-	+/-
Verifiability	+/-	+/-
2. Definition of core datasets		
National	++	+
State		
3. Data format and conceptual model		
Format	+	+/-
Model	+	+/-
4. Data management		
Availability	+	+
Standardized update cycles	+	+
Consistency	+/-	+/-
Provision of large datasets	-	-
5. Data quality and accuracy	+	-/+
6. Common modeling language and tools		
Accessibility	++	++
Usability	+/-	-/+
Usefulness	++	-/+
7. Harmonization of data and metadata		
Coordination	+	+/-
Common models	+	+/-
Organizational		
8. Custodianship		
Well documented	+/-	++
Standardized	+/-	++
Accessibility	+/-	+
Verifiability	+/-	+/-
9. Data sharing and partnership agreements		
Well documented	+/-	+
Standardized	+/-	+
Accessibility	+/-	+
Verifiability	+/-	+/-
10. Business models	++	+
11. Coordinating arrangements		
Definition	+/-	+
Documentation	+/-	+
Web services		
Technical		
12. Application profile	++	+
13. Clearinghouse and geoportal	+	+
Organizational		
14. Clearinghouse organization	++	+/-
Standards		
Technical		
15. Interoperability standards	+	+/-
Organizational		
16. Organizational arrangements for standardization	++	+

a ++, very good; +, good; +/-, first steps in a positive direction; -, not so good; -, bad.

Table 3. Comparison of the Australian and Swiss national SDIs.

On the technical side, both countries are trying to harmonise historical metadatasets. Various metadata profiles have been launched in Australia (ANZLIC metadata profile versions 1.0 and 2.0) and Switzerland (SIK-GIS, CDS) in the last 10 years. Switzerland adopted ISO 19115 for its national profile in 2004, and Australia is in the process of doing so. Both countries are developing freeware and open-source metadata entry tools supporting ISO 19115 (indicator 4 in table 3).

In both Switzerland and Australia, the main Web service is the OGC (Open Geospatial Consortium) Web Map Server (WMS). In Switzerland, a few SOAP (simple object access protocol)-based Web services were developed for metadata, Swiss names, and geocoded addresses. These basic services were coordinated by KOGIS (Coordination, Geoinformation, and Services Division). Other specialized Web services (e.g., for geodetic transformations) are offered by national agencies (e.g., the national mapping agency swisstopo has services for conversion of national map coordinates [Swiss grid] to geographical coordinates [WGS84 datum, etc.] [http://www.swisstopo.ch/en/online/calculation/index]), but these are not coordinated by the national SDI and thus not linked directly (e.g., by a common portal).

Geoscience Australia offers similar Web services, for example, conversion of static GPS data into Geocentric Datum of Australia (GDA) and International Terrestrial Reference Frame (ITRF) coordinates. Other services are offered by other national agencies. As in Switzerland, WMS is the most commonly used standard in Australia. In Switzerland the application profile for Web services already exists, and in Australia it is being developed on the national level by ANZLIC (indicator 12 in table 3).

Neither country has a national clearinghouse as such, but the metadata catalogue serves the function of a search engine. Geoscience Australia, the national mapping agency, lists institutions offering maps. ANZLIC has coordinated an assessment of services provided by the Australian SDI (indicator 13 in table 3).

The role of KOGIS as the coordinating agency for provision of basic services in Switzerland has been questioned. The upcoming legislation on geoinformation will codify federal standards for modeling, acquisition, and exchange of spatial data; regulate copyright and privacy issues; and assign responsibilities for coordination of spatial data. Each Australian state has its own clearinghouse, which determines policies, the institutional framework, and technical standards, while ANZLIC provides national standards and policies for all jurisdictions to implement.

Our indicators apply easily to the two national SDIs, even though the cultural, organizational, and legal contexts differ significantly between Switzerland and Australia. The indicators are still not suitable for assessing SDIs from a cost–benefit point of view, but they do help identify best practices and targets for improvement or for cooperation between countries and institutions. For example, Switzerland can offer technical solutions, whereas Australia can provide excellent expertise on organizational issues.

CONCLUSIONS

We have offered a framework for comparing SDIs on the basis of Web services and data and metadata management, taking a holistic approach encompassing technical and organizational factors.

The SDIs have to reflect the complex organizational, institutional, and technical patchwork of the federal systems of Switzerland and Australia by including local and national representatives and experts.

Australia has a longer history of SDI development and therefore has more results, such as the two metadata cataloges, with which it tested and developed different technologies (Z39.50, three metadata standards). The SDI is very well documented and has clear guidelines, for example, for adding metadata to the ASDD metadata catalogue. However, the existence of two independent metadata catalogues confuses users and complicates interoperability.

Switzerland has a strong data modeling tradition, especially in cadastral datasets. The common modeling (conceptual schema) language INTERLIS, which can be used with a variety of free tools, is an important contribution to interoperability. All SDI components in Switzerland have to provide user interfaces in at least two languages: French and German. The multilingual solutions may be applicable to other countries.

Both countries struggle with inhomogeneous and inconsistent metadata. Common metadata–spatial-data models are especially feasible in Switzerland, where the nationally standardized model for cadastral data, for example, allows integration of different layers. Both countries recognize that free metadata acquisition tools must be offered by the government to help coordinate and facilitate metadata management. In Switzerland these tools are provided by KOGIS (geocat.ch) using the Swiss profile of the ISO 19115 standard. In Australia this work is in progress.

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