Considerations for Spatial Data Infrastructure (SDI)

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Abstract

Spatial Data Infrastructure (SDI) in the broader sense is the technology, policies, standards, and human resources necessary to acquire, process, store, distribute, and improve the utilization of the geospatial data of an organisation, or nation. SDI is the set of data, technologies, skills, and policies that gives users access to geographic information according to their requirements. In the narrower sense, SDI is a geoportal (or Web Map Server) developed as a one-stop Inernet access point to geodata stored in many different data servers distributed across an organisation's intranet, or the Internet. Generally, 'map images' (e.g. jgp, png, or tiff images) are distributed across the network, not the actual data itself. The objective of developing SDI is to facilitate the use of geospatial information, e.g. in disaster management, defence, environmental protection, planning, commercial (e-)business, e-government, and by society as a whole. Most nations already have an SDI of some form operational today, with varying degrees of sophistication and effectiveness. This paper summarises considerations for SDI with a special focus on the Kingdom of Saudi Arabia.

Keywords

Spatial Data Infrastructure (SDI), Web Map Services, Geoportals, Kingdom of Saudi Arabia (KSA)

Introduction

Geographic information is critical to promote economic development, stewardship of natural resources, environmental management, and emergency response. Modern technology now permits improved acquisition, distribution, and utilization of geographic (or geospatial) data and mapping. An SDI shall advance the goals of the National Information Infrastructure, avoid wasteful duplication of effort, and promote effective and economical management of resources by Federal, State, and local governments (US Executive Order 12906, Clinton Administration, 1994).

The above means that there is a market-pull for SDI (*GI promotes economic development*) as well as a technology push (*Modern Technology now permits …*). Also, because of the complexity of the task, there is a strong need for co-operation.

Advantages of introducing an SDI in large organisations or at the national scale are (Williamson et al., 2003):

- Reduced costs in geospatial data production,
- Avoidance of redundant data acquisition,
- Decreased expenditures of time and money in access to geospatial data,
- Enhanced data exchange between organisations and user domains,
- Increased efficiency in the use of geospatial data,

- Increased efficiency in the development of services, using existing data and standards,
- Supply of more valuable data as a basis for decision support,
- Better political decisions, based on more easily accessible data,
- Possibility to come to consensus across institutional boundaries,
- Expansion of markets,
- Easier collection, communication and transfer of knowledge.

A national SDI typically consists of (Rhind, 2000):

- A national 'topographic template', including: a national geodetic reference system (geodetic control), ortho-imagery, elevation data, transportation, hydrographical data, governmental units, cadastral information, and other spatial information,
- Suitably trained people
- Training and education facilities
- Sets of laws, protocols and standards to ensure that the infrastructure operates safely, effectively, and efficiently
- Hardware and software (computers, communications networks, GIS, etc.), and
- Adequate financial resources.

Objectives

The objective of this paper is to summarise general conceptual considerations for an SDI on the national scale. The Kingdom of Saudi Arabia is used as an example.

Materials & Methods

Phoenics GmbH is co-operating with Prof. Konecny, of the University of Hannover / Germany, in providing consultancy services on the topic of introducing an SDI at the national scale in the KSA to the Ministry of Municipal and Rural Affairs (MoMRA, Riyadh). In this context, a comprehensive literature and Internet research was carried out, and the present situation prevailing at MoMRA was analysed.

Results & Discussion

SDI Elements

Elements of an SDI (in the broader sense of the definition given above) exist in most countries today, but with varying degrees of sophistication and effectiveness. Examples of existing elements from the KSA include elements of the national 'topographic template', such as:

- The 1: 50,000 scale military topographic map of Saudi Arabia,
- The new geodetic reference system, including fiducial stations and a network of Continuously Operated Reference Stations (CORS, Fig. 1),

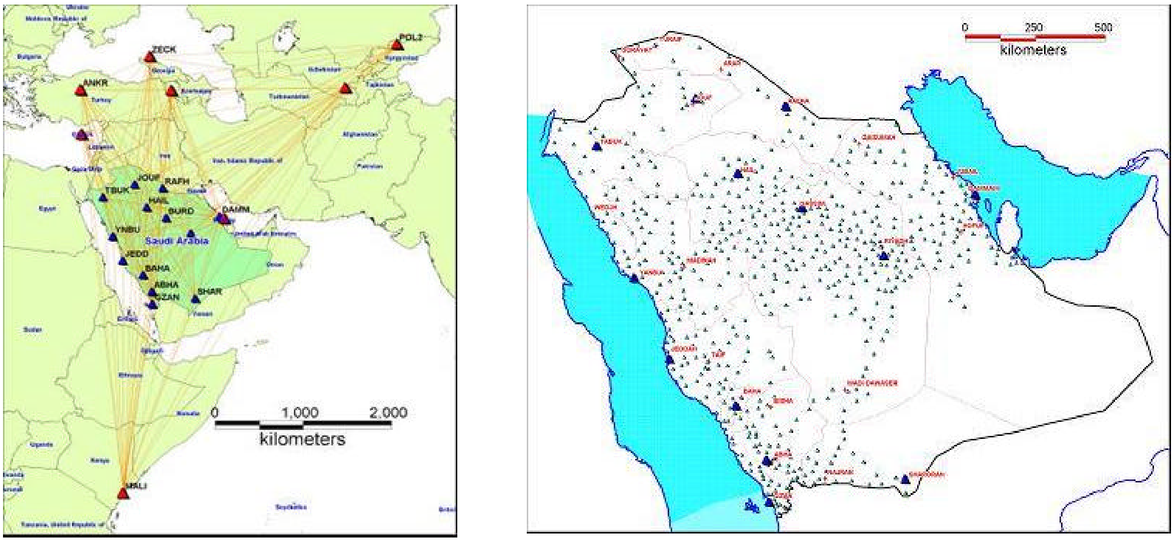

Fig. 1: Fiducial stations and CORS of the new geodetic reference network of the KSA (maps courtesy of MoMRA).

- Elevation data: (i) on the national scale, such as those derived from the Shuttle Radar Topography Mission (SRTM), (ii) on the local scale, such as those measured in stereopairs of air photos during numerous projects, or derived from laser scanning technique (Fig. 2),

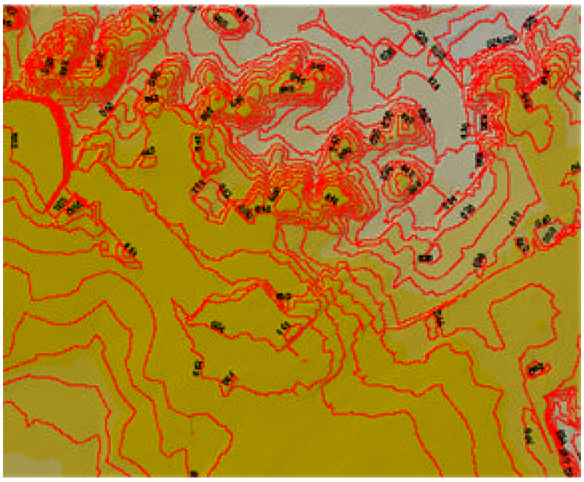

Fig. 2: Example of a DEM measured at the local scale (1: 1,000) from air photos in Riyadh (prepared by Phoenics GmbH).

- Geospatial vector data, resulting from numerous past and present line mapping projects at scales 1: 1,000 to 1: 10,000,
- Low, medium, and high-resolution satellite imagery (Fig. 3),

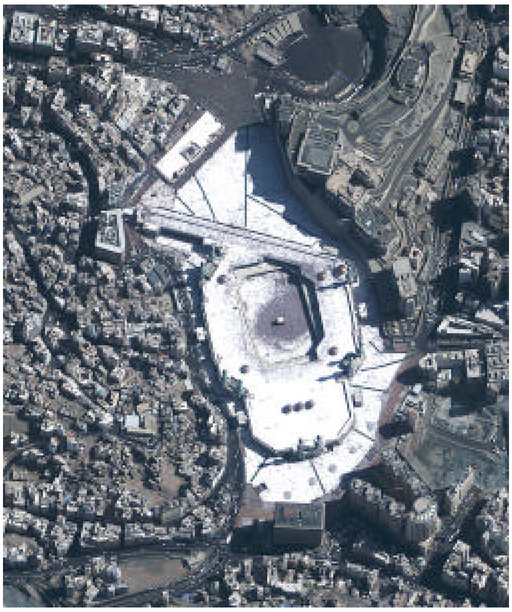

Fig. 3: Subset of a QuickBird look on Makkah (image source: Digital Globe).

- Aerial photographs and orthophotos derived thereof,
- A database design for a geospatial database (Fig. 4).

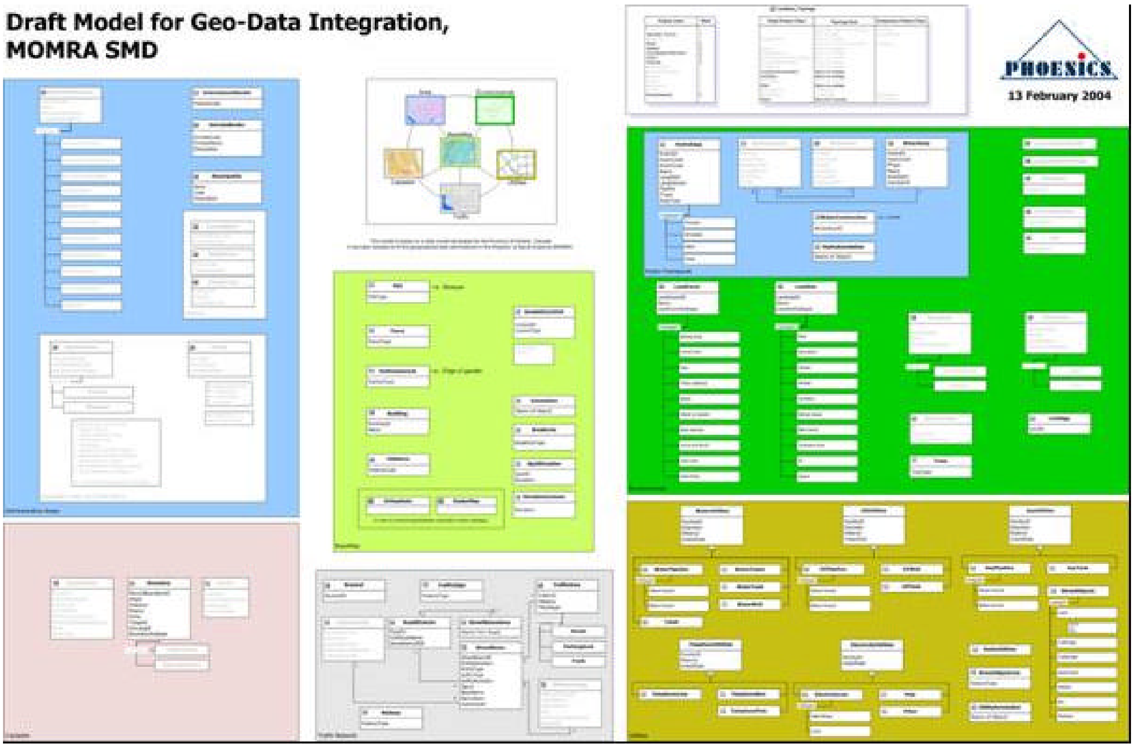

Fig. 4: Draft model for geodata integration in the KSA (prepared by Phoenics GmbH).
Elements of the proposed geospatial database include a base map (light green), environmental data including hydrology (dark green, and blue), utilities (brown), traffic infrastructure / networks (grey), cadastral data (pink), and administrative boundaries (blue).

In the case of the KSA, as in most countries, several elements of an SDI remain to be developed or are being developed presently. These include:

- Densification of the network of CORS with real-time kinematic service (one station every 100 km),
- Implementation of the Geospatial Database,
- Generation of Digital OrthoPhotos (DOP) for all aerial photography projects,
- Internet and/or intranet service to make geospatial data easier available,
- Further development of a high-speed, broad-band computer network,
- Development of a Web Map Service (WMS).

When an SDI is introduced, a number of existing standards should be adhered to. Basic purposes of such standards are to ensure **portability**, **inter-operability**, and **maintainability** of the system.

The ISO/TC 211, 19100-series of standards on "Geographic Information / Geomatics" (www.isotc211.org) is a family of independent, or consensus standards. It is a collection of independent abstract standards for creating and managing a GIS and SDI. Examples of standards from this series include:

- ISO 19101 Reference model
- ISO 19107 Spatial schema
- ISO 19111 Spatial referencing by coordinates
- ISO 19113 Quality principles
- ISO 19114 Quality evaluation procedures
- ISO 19115 Metadata
- ISO 19117 Portrayal (= graphical representation of features)
- ISO 19118 Encoding (for data exchange, recommending XML)
- ISO 19127 Geodetic codes and parameters
- ISO 19135 Procedures for registration of geographical information items
- ISO 19136 Geography Markup Language
- Etc.

In addition the ISO/TC 211 independent consensus standards, the Open Geospatial Consortium (OGC), Inc. publishes *de facto* industry standards, developed by a strong industry consortium.

Web Map Services (WMS), or Geoportals

Internet / intranet technology today provides fast and easy sharing of geospatial information between co-workers within the same agency or between organisations. OGC's 'Web Map Service' (WMS) is the primary specification for requesting maps and visualization via the Internet. Its "GetMap" requests are preceded by a "GetCapabilities" request to ascertain a server's available "layers" of information, and its rendering and processing abilities. WMS transfer "map images", i.e. visual representations of geodata, not the data itself. Maps are conveyed in common raster formats such as PNG, JPEG / JFIF and JPEG2000; TIFF, or occasionally in vector formats such as W3C's Scalable Vector Graphics (SVG), CGM, or W3C's WebCGM. Maps may also be encoded as GeoTIFF. The choice of map encoding depends on the graphical content to be conveyed (e.g., continuous vs. discrete colour variations; transparency; colour depth) and the capabilities of the client viewer.

WMS or geoportals are looked at as the Internet access point, front-end and Graphical User Interface (GUI) of SDI. They are useful to explore the content of geodatabases set up by the individual data providers. Geoportals do not store or maintain geographic data. The data are distributed in many topographic thematic servers across the Internet. Each server is maintained by the organization responsible for the data. WMS users are able to discover and view the maps of their choice, letting the geoportal contact the necessary servers and combine the data (Fig. 5).

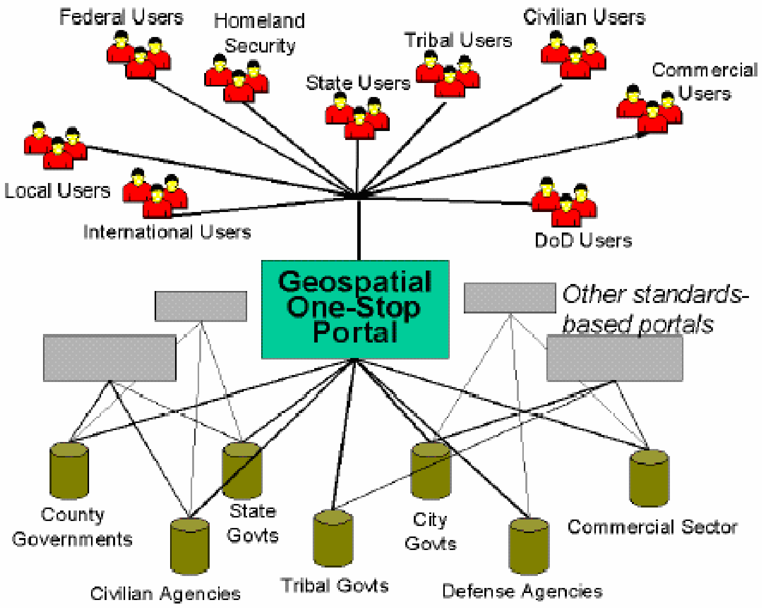

Fig. 5: General structure of WMS, or Geoportals
(image source: OGC, Inc., 2005, www.opengeospatial.org).

The OGC WMS specification standardises the way in which maps are requested by clients and the way that servers describe their data holdings. While some geoportals allow viewing map images of data provided by only one data provider or server, many others allow viewing geodata from many servers distributed across the Internet. This requires interoperability of the service and servers, which is reached by following OGC and ISO/TC 211 19100 standards.

An advantage of geoportals which integrate data from distributed servers is that always the latest version of the geodata, as updated by the individual data provider, is presented. Another advantage is that all users of the system have access to the same information.

As the Internet technology matures, geoportals are viewed as one big step from desktop GI-Systems of the past and present towards online-GIS. However, comprehensive data analysis capabilities today are generally not included in the functionality of geoportals. Many existing applications are restricted to basic functionality, such as overlaying map images requested from distributed servers (WMS), zooming and panning a map image, measuring distances and areas, displaying a map legend, and retrieving metadata describing the data source, as well as attribute data describing individual map features (Web Feature Services, WFS and Web Coverage Services, WCS).

Examples of Geoportals

United States: US National Map (Fig. 6).

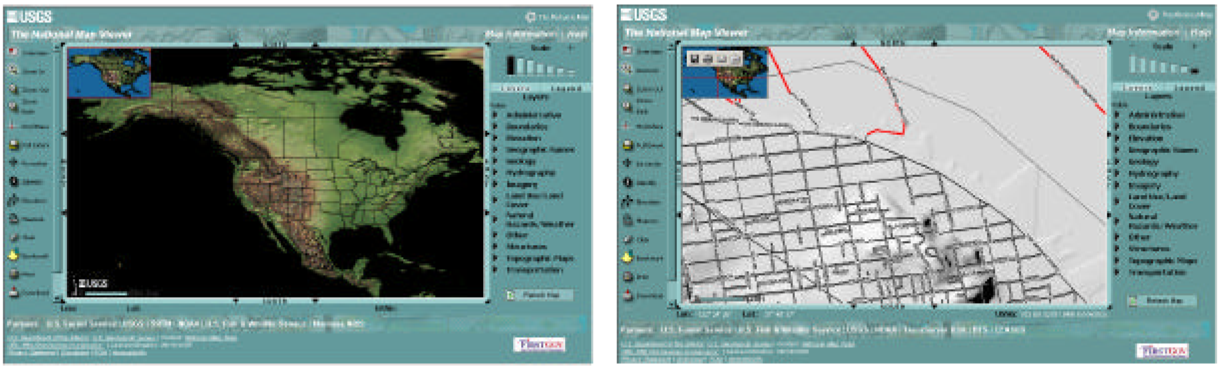

Fig. 6: Screenshots from the US National Map Internet access point (http://nationalmap.gov).

Europe: INfrastructure for SPatial InfoRmation in Europe (INSPIRE, Fig. 7)

INSPIRE aims at making available relevant, harmonised and quality geographic information to support formulation, implementation, monitoring and evaluation of EC policy-making with a territorial dimension or impact. INSPIRE target users include policy-makers, planners and managers at European, national and local level, as well as citizens and their organizations. Possible services include the visualization of information layers, overlay of information from different sources, spatial and temporal analysis, etc.

Fig. 7: Screenshots from the European INSPIRE geoportal (http://eu-geoportal.jrc.it).

The INSPIRE EU Geo-Portal is established on standards and specifications from European, International and industry consensus building processes (ISO, CEN, OGC, W3C), as laid down in the INSPIRE Guidelines, in order to attain the interoperability of data and services in support of the architecture. Standards produced by the ISO/TC211 (ISO 19100 series of standards for geographic information) and the OpenGIS Consortium Ltd. (OGC) are observed. These initiatives specify methods, tools and services for data management, acquiring, processing, analyzing, accessing, presenting and transferring such data between different users, systems and locations. Results of other standardisation initiatives can be considered where necessary and appropriate. Information on standards is also given in the Standards section of the Geo-Portal.

ISO 19100 series of base standards are implementation neutral. Some of these may be used by the market directly (like ISO 19113 Quality principles, ISO 19109 Rules for Application Schema, ISO 19103 Conceptual Schema Language, etc.) while others need to be implemented as software components. Implementation specifications has mainly been developed by OGC, more and more taking the ISO 191xx implementation neutral base standards as the basis for platform specific implementations (CORBA, COM/OLE, SQL, XML, etc.). This process may result in amendments to the base standards, submitted to ISO, either as technical corrigendum or as new ISO standards. In this way, ISO/TC 211 and OGC complement each others efforts to ensure interoperable solutions to GIS.

Germany: GeoData Initiative (GDI-DE, Fig. 8)

Fig. 8: Screenshots from the German GDI geoportal (http://geoportal.bkg.bund.de/).

By resolution adopted on 15 Feb. 2001, regarding the use of geo-information in Germany, the German parliament requested the Federal Government to take political measures in order to rapidly drive forward the establishment of a national geodata infrastructure as a public measure serving to improve the infrastructure. The Federal Government, the German States, and private enterprises are called upon to utilise most effectively and further improve, by way of trustful and close cooperation, the chances inherent in geosciences and geoinformation. The resolution states that basic geodata are mostly being acquired using public resources and that they represent a public infrastructure.

The National Geodata Base (NGDB) is the core component of the Geodata Infrastructure Germany (GDI-DE), which consists of Geo Basic Data, Thematic GeoData, and their respective metadata. By means of the geodatabase, a geoinformation network, services, and standards, GDI-DE lays the foundation for the acquisition, evaluation and application of geodata, which are employed by users and providers in public administration, the commercial and non-commercial sectors, in science and by citizens to meet the citizen needs.

The setup of the GDI-DE takes place in a three-stage, co-ordinated process.

- The first stage aims at establishing the Federal Government Meta Information System for Geodata (GeoMIS.Bund), serving the search for geodada administered by the Federal Government.
- The second stage aims at harmonising geodatabases and at the development of interfaces, data conversion modules, standards, and methods for data integration. The file of basic data contained in the NGDB has to be verified by the different departments involved, by way of an inventory and analysis of requirements. With the harmonisation of geodata and the definition of geodetic reference systems the European context is taken

into consideration. The new ISO-conform data model (called ALKIS/ATKIS) is a common basis for a cross-departmental feature type catalogue.

- The third stage aims at stepwise implementation of the National Geodata Base.

In order to be able to develop and operate the geodata infrastructure it is necessary to implement an organisational and management structure which serves the purpose of coordinating and administrating business operations on the local, regional, national, and transnational levels. Against this background the GeoData Infrastructure Germany can be implemented only on the basis of politically imposed instruments of action.

The German Bundestag has acknowledged the progress made in the establishment of the GDI-DE. The decision requests for taking advanced measures in order to eliminate remaining deficiencies and push the use of geo-information in Germany further ahead.

In September 2005 the Geoportal.Bund was put online as the Internet access point of the German Geo-Data Infrastucture (http://geoportal.bkg.bund.de/). The service is available in two versions, a "base viewer", and an "expert viewer". Geoportal.Bund is a WMS based on interoperability among distributed geospatial services accessible over the Internet, presently including topographical data of various sources, meteorological data, air photos, etc.

Models for funding SDI

According to Rhind (2000) there are at least four different models for funding an SDI:

- Funding by central or local government from the national budget;
- Funding through payments made by customers, collected by the private sector;
- Funding through payments made by customers, collected by the public sector; and
- Funding on the basis of sponsorship, advertising or other indirect methods. This could be taken to include near-market applied research and development.

Different approaches have been followed successfully in different countries, and it seems largely a political decision which of these models is followed.

Strategy for SDI implementation

In SDI implementation, a coordinating lead agency should be implemented on the national level to work in close collaboration with other national, provincial and municipal agencies, and private industry organisations. In many cases the national mapping authority will be an adequate organisation to take the lead. The national lead agency shall have powers to enforce SDI implementation rules and standards. The implementation strategy may include the following steps:

- Development of a "meta-meta model", or conceptual description of the proposed SDI with natural language.
- At the "meta-model" level, conceptual schema language provides the semantic and syntactic elements used to rigorously describe the conceptual model of an SDI, and to convey consistent meaning. A conceptual model described using a conceptual schema language is called a conceptual schema. The conceptual schema language prescribed in the ISO 19100 series of standards is Unified Modeling Language (UML)

- The “application model” completely defines data elements (classes) of the SDI and their interrelation. The heart of the application model is a detailed description of the data structures. This description is called an application schema.
- The “data model” contains the data being collected for an application and the services that operate on the data. The data model includes all features and their describing data that make up the complete geospatial database as the backbone of the SDI.

Conclusions

Introducing an SDI on the national level has ample advantages, from reducing costs of collecting geospatial data to enabling access of all data users to the same pool of geospatial information. In most countries many individual elements of an SDI already exist. Introducing an SDI typically involves “tidying up” and harmonising existing datasets and SDI elements, and making them more easily accessible to users, often by introducing a Web Map Service, or geoportal. The process of introducing a national SDI as a whole is complex, because it involves legal, financial, technical, and organisational tasks. Often it involves collaboration between organisations (data providers) that did not previously co-operate with each other. While technical solutions today are available to introduce WMS giving numerous data users access to numerous geospatial data servers distributed across the Internet, the most challenging task may be that of co-ordinating the work between the individual organisations involved. Therefore, strong project leadership seems to be key. An implementation plan with clearly defined goals should be drawn up before commencing the exercise, and should be followed during the implementation phase.

Phoenics GmbH (www.phoenics.de) has ample experience in providing consultancy services in most stages of the topic of implementing an SDI, from developing a conceptual description of an SDI to implementing the data model.

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