Assessment of spatial data infrastructures

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Abstract

A Spatial Data Infrastructure (SDI) is an evolving concept, essentially consisting of policies, institutional arrangements, Geographical Information Systems (GISs), data bases, networks, Web services and portals to facilitate and coordinate the availability, exchange and sharing of geospatial data and services between stakeholders from different levels. This article aims to provide some information on the role and value of SDIs and their potential relationship with, and contribution to other geospatial and evidence-based tools and technologies within the South African planning context and system. For this, it provides a brief overview and comparison of the key characteristics of the SDIs in South Africa, China, Brazil, Australia and India. The article highlights some of the complexities and use of an SDI and the value of, and need for an SDI to support the spatial and land development planning envisaged in the Spatial Planning and Land Use Management Act (SPLUMA).

RAMING VAN RUIMTELIKE DATA-INFRASTRUKTUUR

Ruimtelike data-infrastruktuur (SDI) is ’n ontwikkelende konsep, bestaande hoofsaaklik uit beleid, institusionele reëlings, geografiese inligtingstelsels (GISs), databasisse, netwerke, Web-dienste en -portale ten einde die beskikbaarheid, uitruil en deel van ruimtelike data en dienste tussen belanghebbendes van verskillende vlakke te fasiliteer en te koördineer. Hierdie artikel het ten doel om ’n oorsig te bied oor die rol en waarde van SDIs en hul potensiele bydrae tot ander ruimtelike en besluitnemingsondersteuningstelsels en platforms binne die Suid-Afrikaanse beplanningskonteks. Vir hierdie doel bied die artikel ’n kort oorsig en vergelyking van die belangrikste eienskappe van die SDIs in Suid-Afrika, China, Brasilië, Australië en Indië. Dit gee ook ’n aanduiding van die kompleksiteit, gebruik, waarde en behoefte aan ’n SDI ten einde ruimtelike beplanning en grondgebruikbestuur soos in die vooruitsig gestel deur die Wet op Ruimtelike Beplanning en Grondgebruikbestuur (SPLUMA) te laat realiseer.

TLHAHLOBO A DI SPATIAL DATA INFRASTRUCTURE

Spatial Data Infrastructure (SDI) ke monahano o phelang o fetoha, e kopantseng maano, ditumellanotsa di Institute Geographical Information Systems (GIS), didatapeisi, dikamano, ditshebeletso tsa interneteng, ho tsamaisa, ho fumana le ho arola tsebo ya dibaka le ditshebeletso mahareng a batho ba amehang methating eohle ya taba tsena. Serapa sena se sheba ho fan aka tsebo ya bohlokoa le karolo e di SDI e di bapalang, hammoho le dikamahano le kenyelletso tse ka bang teng ho dithulusi le thekenoloji tse amahanang le dibaka tse kholo mererong le ditshebetsong tsa Afrika Borwa. ka baka la see, serapa sena se fan aka kakaretso e nyane le dipapiso tsa di SDI tsa Afrika Borwa, China, Brazil, Australia le India. Serapa sena se bontsha dintho tse ngata tse fapaneng, le tshebeliso ya SDI hammoho le bohlokoa ba SDI ho tshehetsa merero ya ho tswedisa pele dibaka tse kholo le naha e tsamaisoa ke lekana le bitsoang Spatial Planning and Land Use Management Act (SPLUMA).

1. INTRODUCTION

Geospatial data have many applications in many fields, particularly in planning. One of the distinguishing characteristics of the use of such data is that the same, common, base geospatial data sets are used by many different users for diverse applications. There is also a much greater awareness among the lay public and professionals of the power and utility of geospatial data. This has been stimulated by the ready availability of ‘virtual globes’ such as Google Earth; online repositories of user-generated geospatial data (also known as ‘Volunteered Geographical Information’ (VGI) [Goodchild, 2007: 28-30]), such as OpenStreetMap, and Global Navigation Satellite System (GNSS)[1] receivers embedded in consumer devices such as vehicle navigation systems and mobile telephones. Consequently, there is a growing demand for, and supply of geospatial data.

Even though vast quantities of spatial data are often readily available, even for free or very cheaply, they are not necessarily easy for most users to find nor necessarily suitable for their needs. In addition, it is not always easy to assess if the data are appropriate for one’s application (i.e., their ‘fitness for use’) (Cooper, 2013: online).

This has resulted in the development and implementation of ‘Spatial Data Infrastructures’ (SDIs), which are

1. Such as the USA’s NAVSTAR or GPS (Global Positioning System), Russia’s GLONASS (Global Navigation Satellite System), China’s Beidou, the European Union’s Galileo, etc.

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evolving concepts about facilitating and coordinating the exchange and sharing of geospatial data and services between stakeholders from different levels in the geospatial data community (Hjelmager, Moellering, Dado, Cooper, Rajabifard, Rapant, Danko, Huet, Laurent, Aalders, Iwaniak, Abad, Düren & Martynenko, 2008: 1296).

South Africa is no exception, with mention often being made in planning and policy arenas of the need for evidence-based planning and spatial data collaboration (CSIR, 2014). As a developing country, the problem is probably also more complex, with, on the one hand, the need for more and better quality evidence to inform integrated and development planning, and, on the other, a dire need to ensure easily accessible and coordinated spatial data between the wide range of municipalities, provinces and national sector departments that have mandates for spatial development policies and plans (i.e., Departments of Rural Development and Land Reform (DRDLR), Human Settlements, Co-operative Governance, National Transport, etc. as well as the National Planning Commission and Economic Development Department). A need that has recently been amplified and placed under the looking glass by recent integrated initiatives such as the National Development Plan (NDP) in 2011, the recent development of the Integrated Urban Development Framework and the first National Spatial Development Framework in 2014.

Among a range of efforts to establish capacity for Geographical Information Systems (GISs) and geospatial analysis within institutions, this need has also resulted in various initiatives to provide relevant geospatial information in more coordinated and easily accessible ways to practitioners and policymakers through various portals, observatories, atlases and other systems based on geospatial information.

Within the above context, the purpose of this article is to illustrate the role and value of SDIs in supporting the spatial planning and the land development planning envisaged in the NDP and Spatial Planning and Land Use Management Act (SPLUMA) (RSA, 2013), as well as the range of decision-support initiatives, systems, platforms, portals and observatories associated with that aim. This will be done first, by providing some background on planning, specifically spatial data challenges within the South African context. Secondly, it will provide some information on the role, complexities and value of SDIs. For this, it examines not only SDIs in South Africa, but specifically also the roles and characteristics of SDIs in other countries with developing (India and Brazil), federal (Australia) and strong national planning (China) contexts. Lastly, this article highlights some of the complexities and use of an SDI and the value of, and need for an SDI to support the spatial and land development planning envisaged in SPLUMA and the importance of considering the contribution thereof to other geospatial and evidence-based tools and technologies within the South African planning context and system.

The comparative SDI analysis outlined in this article is based on a study on SDIs conducted by the CSIR during 2013-2014, as part of the StepSA project, a collaborative effort aimed at contributing towards spatial temporal evidence for South Africa by the Department of Science and Technology (DST), CSIR and the Human Sciences Research Council (HSRC), that is funded by the DST.

2. BACKGROUND TO SPATIAL PLANNING AND DATA CHALLENGES

South Africa has a vast, and until 1994, an incriminating, tradition of spatial planning with an increased acknowledgement of the value and role of spatial planning instruments in government's planning, resource allocation and implementation. The Constitution makes provision for provincial and regional planning as well as decentralised planning functions at municipal level (Oranje & Van Huyssteen, 2011: 9).

Chapter 8 of the NDP highlights clearly the importance of spatial targeting and planning (NPC, 2011: 259-293). Similarly, this importance was highlighted by a range of initiatives and seminars on spatial targeting spearheaded by National Treasury, the National Planning Commission and the South African Cities Network (SACN).[2] Original spatial planning policies, as set out in the National Spatial Perspective (NSDP) spearheaded by The Presidency (The Presidency, 2006) and the Comprehensive Rural Development Strategy, have been taken forward and refined recently through various key national projects such as the Urban Network Strategy (National Treasury), the focus on functional regions for rural development spearheaded by the Department of Rural Development and Land Reform, and the initiatives to develop spatial perspectives in support of the National Growth Path, spearheaded by the Economic Development Department (EDD). All these initiatives have highlighted the need for enhanced spatial data analyses, coordination and shared use and access.

Most importantly, the Spatial Planning and Land Use Management Act (SPLUMA) (RSA, 2013) requires the three levels of government to prepare spatial development frameworks (SDFs) and introduces a whole new system of land-use management, which, *inter alia*, requires the provision of "clear and accessible information to the public and private sector" (RSA, 2013: 24, Clause 12(1)(g)).

This planning system not only requires a vast improvement in the current land-administration system, but also foresees much better integration between various planning instruments and supporting systems, for example between land use, zoning (land-use rights) and planning (typically the indication of planned use as set out in the SDF) information. While these concepts have elements in common and relate to one another (as illustrated

2 See Spatial Targeting Conference and initiatives on <www.StepSA.org.za>

in Figure 1), land use, zoning and planning are different concepts.

- Land use does not stop at political boundaries. It is the *de facto* usage of the area, whether legal, illegal or uncertain, and is often of mixed uses.
- Zoning/Land-use right is typically indicated by cadastral parcel, even though this can also be a group of parcels, depending on the type of area. It identifies the designated permitted uses, including aspects such as use or function, building height, density, building lines, impervious surfaces, servitudes, responsibilities, etc. Parcels zoned differently can be tied together legally, e.g. the required parking garage for a shopping centre. Land-use rights are used to determine the mix and nature of uses and development of the area and can be used to preserve the character of an area, increase density, or increase the variety of uses, etc. The land-use rights are to be set out in the Land Use Management Scheme, required by law (SPLUMA) for every municipality in the country. This is a major challenge in mainly rural and informal areas.
- Planning (planned use, density and type of area) is usually derived from the broad vision set out in the SDF, but is also based on projections, evidence, key interventions and linked to existing or desired future land use. It should be a systematic assessment to order and regulate land use efficiently,

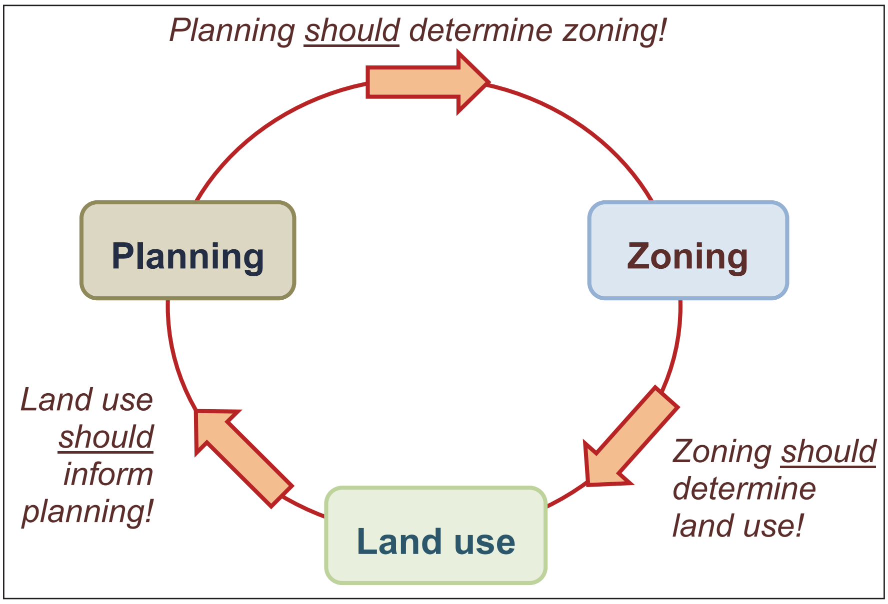

Figure 1: Planning, zoning and land use

Source: Cooper & Schmitz, 2014

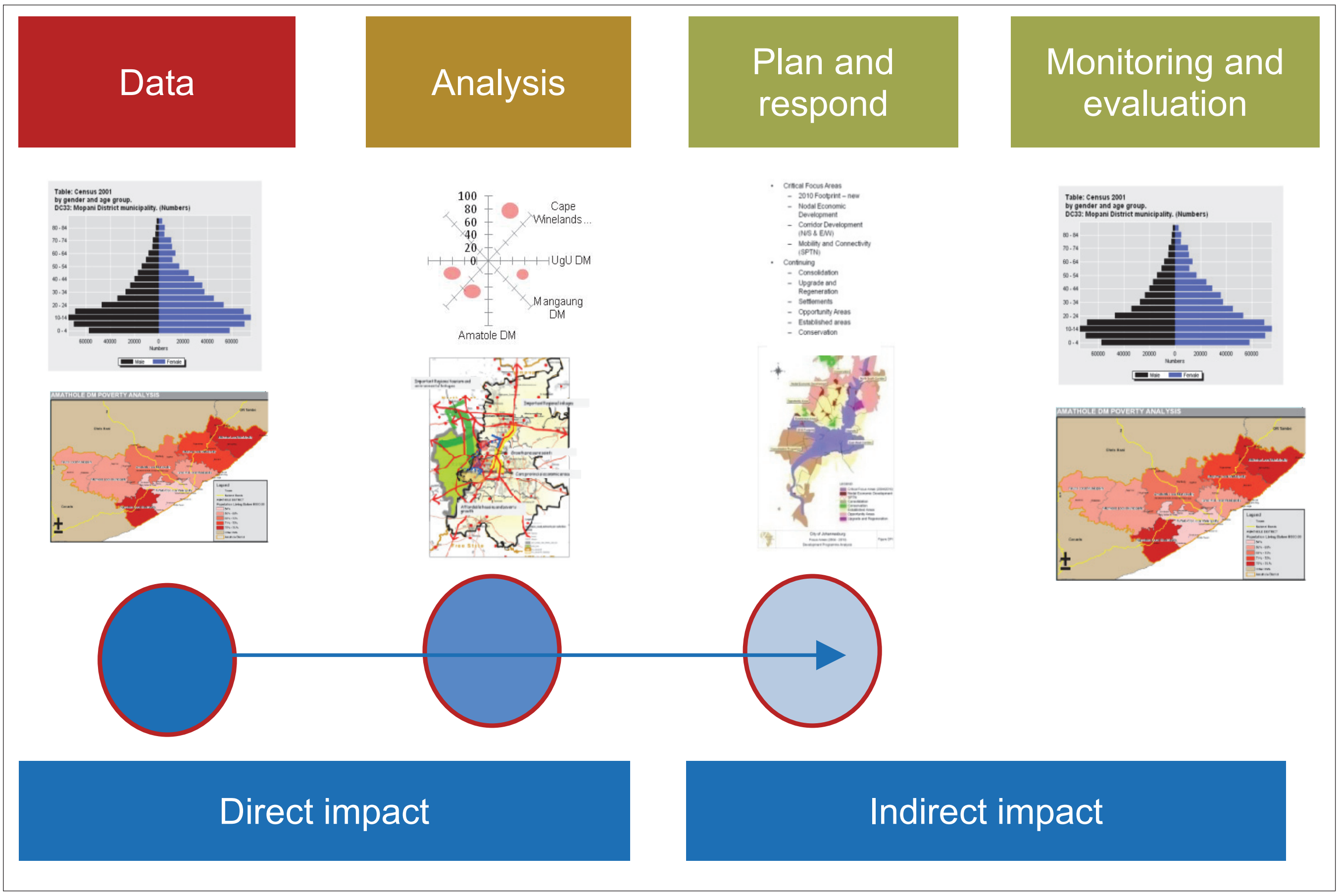

Figure 2: Role and impact of spatial data

Source: Adapted from: Maritz, Le Roux, Van Huyssteen, Coetzee, Mans & Goss, 2010: online effectively and ethically, and reduce land-use conflicts. In addition, the planned land uses are aimed at reaching developmental and spatial outcomes, and take into account the current and potential economic and social conditions, alternative uses, available resources, future demands, aesthetics, and the like.

Planned land use, zoning (legal land use) and land use (real and current use) should obviously form a virtuous circle, as shown in Figure 1. There is already a challenge in ensuring more synchronisation between planned, zoned and current use (and thus data sets), as future desired (planning) and legal (zoning) land uses are inherently influenced by political and administrative processes at various levels of government. Plans are amended in cycles, but legal rights are amended by application and thus need to be recorded continuously (a challenge for recording within low-capacity municipalities) and neither is the same as the *de facto* land use (which often is bound to be outside the formal legal land-use system).

An SDI is particularly useful for supporting evidence-based planning, as it should provide ready access to geospatial data sets, such as the spatial plans and zonings of other authorities, legal restrictions (such as protected areas and servitudes), the cadastre and deeds, the actual and historical land use, the topography that facilitates or constrains various types of land use, population dynamics, economic activities, natural resources, transport networks and other infrastructure.

Whilst the challenge in the difference between planned land uses, land-use rights and current land uses, as set out in Figure 1, is shared within many countries, South African SDI development and progress faces additional challenges.

First, given the current drive for implementation of SPLUMA, a major challenge in the short term is that many of the data set requirements, standards and land-use categories are currently in flux and under development and refinement, involving many working groups and projects for the DRDLR to address, with enormous opportunity for innovation, but also a 'chicken-and-egg situation' that requires an incredible effort of coordination and synchronisation.

Secondly, one of the major challenges is the fact that all of the above and any operational SDI require a sound land-administration system (cadastre) on which all these data sets hinge. While South Africa has a single, integrated national digital cadastre, it is not always kept up to date and depends on a range of role players to ensure its upkeep. One of the major challenges for SPLUMA remains the synchronising of data sets between relevant role players (e.g. municipalities, surveyors general and registrars of deeds), in capturing and recording changes in the cadastre and legal land-use rights, as well as the tracking and monitoring of use, changes to rights, restrictions and responsibilities, and development related to such land parcels.

As is clearly illustrated in Figure 2, the availability and quality of geospatial data not only have direct impact on recording, analysis and planning, but also influence the possibility for monitoring and evaluation, and thus the capacity of government to evaluate outcomes and targets.

Within this multilayered context, a range of initiatives has been kick-started to address the myriad of needs for spatial data analyses, coordination and access. This includes major initiatives by DRDLR related to the implementation of the South Africa Spatial Data Infrastructure (SASDI), the development of a Spatial Data Repository and major strides in developing land-use categories and guidelines for SDFs and land-use management systems. Statistics South Africa has also made strides in spatial representation of official data sets.

In addition hereto, the Spatial Temporal Evidence Platform for South Africa (StepSA), a joint initiative between DST, CSIR and HSRC, provided a platform for collaborative innovation in developing indicative data sets and indicators to support planning processes, especially enabling enhanced understanding of spatial and temporal relations between and within urban and rural areas, and to spearhead development of innovative technologies (i.e. Urban Simulation) to support simulation and modelling of planned interventions in order to test implications of, and on planned land uses.

Other initiatives in support of practitioners and policymakers include the Gauteng City-Region Observatory, a joint initiative by Gauteng Province and the Universities of Johannesburg and the Witwatersrand, aimed at supporting planning and decision-making in the Gauteng City Region and providing coordinated spatial information between the various metros, and the Spatial Planning Information System (SPISYS), developed by DRDLR to support municipal and provincial planning in the Free State and Northern Cape. Other theme-specific systems and platforms also exist, for example, a system to assess the suitability of land for human settlement, developed by the Housing Development Agency (HDA) and the South African Risk and Vulnerability Atlas (spearheaded by DST and CSIR).

One of the key government initiatives that could contribute in this field is the national observatory for spatial data and analysis, emanating from South Africa's National Development Plan, which has as Objective 48, "Establish a national observatory for spatial data and analysis", where such an observatory "would collect, continually update and analyse data and other information relevant to spatial planning" (NPC, 2011: 66, 291).

It is evident that within this multilayered, inter-dependent, often scattered and fast-changing landscape of planning in South Africa, the range of policies, initiatives and spatial platforms, systems and observatories, all aimed at contributing towards generating, disseminating and co-ordinating spatial data, would benefit tremendously by being part of a well-functioning SDI. Each could have its own value-added data sets; its data sets, analyses and other services can be provided through the SDI, as well as directly to its participants.

3. A BRIEF OVERVIEW OF SPATIAL DATA INFRASTRUCTURES

As set out in the Introduction, an SDI is then more than merely the technology of a Geographical Information System (GIS); it is generally considered to be the collection of technologies, policies (including standards) and institutional arrangements that facilitate the availability of, and access to geospatial data. It provides a basis for geospatial data discovery, evaluation and application for a variety of users and providers (Nebert, 2004). In addition, an SDI should facilitate 'mash-ups', that is, existing services and/or content (data) from multiple sources, even multimedia, aggregated, integrated or 'mashed-up' together.

An SDI needs to cater for 'soft' issues, such as business models, cooperative agreements, legislation, marketing, education and structures (such as committees) for coordination and management. One SDI can be part of another SDI, either functionally such as a national water SDI within a general national SDI, or hierarchically such as the Europe-wide SDI, INSPIRE (Infrastructure for Spatial Information in the European Community) (European Parliament, 2007), which is based on the national SDIs of Member States (Cooper, Rapant, Hjelmager, Laurent, Iwaniak, Coetzee, Moellering & Düren, 2011: online).

Unfortunately, because of the complexities involved (not only concerning the data[3] and technologies, but also the institutional arrangements and personalities), it takes a long time to establish an SDI, while many seek a quick fix. There is also competition such as from virtual globes, open data repositories and other SDIs. Hence, any SDI has to offer a valid value proposition to justify its existence, including cooperating with other systems and organisations (Cooper, 2013: online).

The primary source for standards for geospatial data is the relevant technical committee of the International Organization for Standardization, ISO/TC 211.[4] As at the end of June 2014, ISO/TC 211 published 55 International Standards and Technical Specifications. On 15 September 2010, as a mark of the quality of ISO/TC 211's work, ISO presented the committee with the Lawrence D. Eicher Leadership Award for "recognition of superior performance by an ISO standards development committee that is helping meet the needs of users of standards worldwide" (Tan, 2010: online).

The United Nations has recognised the need for SDIs and making geospatial data available, for both its own agencies and operations and, through the United Nations Initiative on Global Geospatial Information Management (UN GGIM)[5], Member States, particularly for addressing global issues and building geospatial capacity in developing countries. Bessero, Brodeur, Coetzee, Østensen, Pharaoh & Reed (2013: online) identified over 100 standards relevant for UN GGIM, from ISO/TC 211, the Open Geospatial Consortium Inc. (OGC), and the International Hydrographic Organization (IHO). In a similar vein is the Mapping Africa for Africa initiative of the UN Economic Commission for Africa, for which *Guidelines of Best Practice for the Acquisition, Storage, Maintenance and Dissemination of Fundamental Geo-Spatial Datasets* (Clarke, 2014) are being developed. The guidelines will be available free in order to promote and facilitate SDI development and geospatial data management across Africa. The draft chapters on standards for these guidelines were published recently for comment (Coetzee, Cooper & Rautenbach, 2014).

It is clear that, internationally, SDI initiatives are regarded as crucial, with key standards being vital for both national and international collaboration, planning and monitoring. In South Africa, the need is not only to support the NDP objectives and SPLUMA implementation, but also to support practically the coordinated planning, implementation and monitoring of the efficiency and effectiveness of government across all three spheres, and to enable government to plan and evaluate interventions in order to reach national targets and sustainable development goals. Given this urgency, it is indeed valuable to reflect briefly on the positioning and key attributes of, and challenges with implementing similar initiatives in other countries. Examples from a number of countries with similar complexity in terms of developmental challenges, multilayer planning systems and role players, and at different stages of implementation were selected for comparison. The original desktop analyses and report, on which this article is based, are available in full as part of the StepSA initiative.[6] This research was aimed originally at developing an enhanced understanding of SDIs and the role of auxiliary and value-added data sets, and different role players within the SDI process (Cooper, Das & Coetzee, 2014). The criteria and definitions considered for the SDI assessments were based mainly on the types and subtypes of stakeholders in an SDI (Cooper *et al*., 2011). It is not feasible to duplicate that article in this instance, but it is readily available online for the definitions of the terms.[7] The analysis has been limited, because the documentation of the SDIs of Brazil and China are obviously primarily in Portuguese and Chinese, respectively.

3 The Earth is an irregular oblate spheroid, requiring a variety of coordinate reference systems to project the data, each being a compromise between preserving direction, shape, area, distance and/or shortest route, and with different datums (models of the Earth).

4 *Geographic information/Geomatics*, see <http://www.isotc211.org/Outreach/ISO_TC_211_Standards_Guide.pdf.>

5 See <http://ggim.un.org/.>

6 See <http://StepSA.www.org.za>

7 See <http://icaci.org/files/documents/ICC_proceedings/ICC2011/>

3.1 Spatial data infrastructure in South Africa

SDI-type activities in South Africa began in the mid-1980s with the State Interdepartmental Coordinating Committee for the National Land Information System (CCNLIS), although, at that stage, the NLIS was intended to be only an inventory of available geospatial data sets. CCNLIS also coordinated GIS and related activities in government departments (Cooper, 1993). The needs for a framework for effective governance and access to geospatial data were then well recognised and there was clearly a need for a unit within government with the resources to take NLIS further. Therefore, the National Spatial Information Framework (NSIF) Directorate was established within the then Department of Land Affairs (now DRDLR) in 1997. NSIF aimed at setting in place the technical and policy framework for enabling unimpeded access to, and utilization of geospatial data for effective and efficient governance, planning and decision-making, through all spheres of government (Cooper & Gavin, 2005).

The development of the South African Spatial Data Infrastructure (SASDI) is being facilitated by the Spatial Data Infrastructure Act (SDI Act) (RSA, 2004). This Act was signed into law at the beginning of 2004, but only started to come into effect in mid-2010, for various reasons. The Act also established the Committee for Spatial Information (CSI), which is responsible for implementing SASDI. NSIF developed the SDI Act and is the secretariat for the CSI.

To date, in collaboration with various organisations, the CSI has already made progress in arranging training events (unsurprisingly, there is limited expertise on SDIs in South Africa), determining criteria for the core geospatial data sets and data custodians, identifying the initial set of 10 core data sets and their custodians, drafting policies and establishing its website with a pilot metadata catalogue.[8] The core data sets are: Administrative Boundaries, Imagery, Roads, Social Statistics, Land Use, Land Cover, Cadastre, Hydrology, Geodesy, and Conservation Areas. A challenge is the inclusion of auxiliary and value-added data sets. Metadata is available and hosted by the South African Environmental Observation Network (SAEON) as a pilot, whereas spatial data sets are available via custodians. One of the key challenges for implementation is the limited funding available.

Another key challenge in South Africa is the multiple stakeholder dynamics. Parliament is responsible for the legislation for SASDI, and DRDLR for the regulations; decision-making is with the Committee for Spatial Information (CSI); the main champion is the Chief Director: National Geospatial Information and the secretariat functions are provided by NSIF.

A range of official mapping agencies and data producers exist, i.e. Chief Directorate: National Geospatial Information (NGI); Statistics South Africa; Municipal Demarcation Board; Independent Electoral Commission; Provincial Departments of Traditional Affairs; South African National Space Agency (SANSA); South African National Roads Agency (SANRAL); Provincial Government; Local Authorities; South African Geographical Names Council (SAGNC); Eskom; Department of Water and Sanitation; Chief Surveyor General; Provincial Surveyors General; Department of Agriculture, Forestry and Fisheries; Registrar of Deeds, and Catchment Management Authorities (CMAs). In addition, NGI has a partnership agreement with OpenStreetMap, which will facilitate crowd sourcing data collection.

SASDI will use the standards of ISO/TC 211, OGC and the South African Bureau of Standards (SABS) in general. SANS 1878-1 is the South African metadata profile of ISO 19115. Given the multiplicity of stakeholders, product specification is also being done for describing data-capture projects, based on ISO 19131, and classification is done in terms of SANS 1880, an implementation of ISO 19110. Standards for web services are also being set up.

The term of the current CSI expired on 30 June 2014, and the appointment for the next CSI is still in process. However, the momentum has been established and work on SASDI is continuing.

3.2 Spatial data infrastructure in China

The People's Republic of China (PRC) has a complex hierarchy of administrative areas with five main levels, but with a variety of special cases making additional half-levels. The top level (provincial level) consists of 22 provinces (PRC also considers Taiwan to be its 23rd province), five autonomous regions (primarily for ethnic minorities, including Tibet), four directly controlled municipalities (Beijing, Tianjin, Shanghai and Chongqing), and two special administrative regions (Hong Kong and Macau). Effectively, there is much *de facto* autonomy within the system, while Hong Kong and Macau are mostly self-governing regions. The result is that the governments at provincial level have their own surveying and mapping authorities and their own geomatics centres, which, among other activities, run the SDIs at provincial level. It is also likely that there are surveying and mapping authorities at the lower levels (prefecture, county, etc).

The national surveying and mapping agency for China is the National Administration of Surveying, Mapping and Geoinformation (NASG).[9] Attached to the NASG is the National Geomatics Center of China (NGCC), with 150 staff members.[10] NASG is responsible for China's national SDI, the National Fundamental Geographic Information System (NFGIS).[11]

Unfortunately, as spatial data is highly controlled in China, very few data sets are publicly available. NFGIS appeared to have been disabled recently, but is now back up

8 See <http://www.sasdi.gov.za/>

9 See <http://www.sbsm.gov.cn/>

10 See <http://ngcc.sbsm.gov.cn/article/en.>

11 Can be accessed at <http://nfgis.nsdi.gov.cn/nfgis/english/default.htm>

and running. NFGIS provides only a few classes of data, and only at a scale of 1:4 000 000. These include primarily main rivers (level 5 and above), main roads, railways, cities (county and above), boundaries (county boundary and above), with no value-added or specialist data sets evident. There is also a general open data portal in Hongkong.[12] The SDI is managed by one 'node' and funded by Government. The secretariat and distribution functions are undertaken by the National Geomatics Center of China, part of the National Administration of Surveying, Mapping and Geoinformation (NASG). China is very active in ISO/TC 211, adopting and translating its standards, contributing to the multilingual glossary of terms, leading projects, and hosting several ISO/TC 211 Plenaries, including the 39th in November 2014.

3.3 Spatial data infrastructure in Brazil

Brazil has a decentralised form of government, with no central agency to take the lead with developing a nation-wide SDI. Instead, the initiative was taken initially from outside the system by information technology organisations (Câmara, Fonseca, Monteiro & Onsrud, 2006). However, the Presidential Decree Nbr 6666 of 27 November 2008 established the legal framework for the implementation of the Brazilian national SDI, with the Instituto Nacional de Pesqisas Espaciais (INPE) as the responsible agency.[13]

The Brazilian SDI is known as Infrastructura Nacional de Datos Espacios (INDE), for which there is a viewer.[14] Interestingly, the viewer does not use the INDE data to provide the backdrop, but uses OpenStreetMap as its default, with the options of using instead Google Satellite, Google Physical (obtained by selecting Terrain for Google Maps), or Google Street (the default map theme for Google Maps). The viewer presents a wide and extensive variety of core data, including agriculture, fisheries, health, geology, geomorphology, vegetation, climate, weather, education, energy, population, transportation, etc.

In addition to the core data sets, the Brazilian SDI also includes value-added and specialist data layers. Thematic data are presented with a default classification, but in support of decisions, the data can be reclassified and viewed comparatively in different layers. Whilst the data can generally be downloaded, field descriptions and other metadata are only available for some data sets. The viewer allows the available metadata for a data set to be linked to several social media sites (Foursquare, Reddit, Facebook and StumbleUpon).

The SDI is driven by the Brazilian Government, with secretariat services provided through the Instituto Nacional de Pesquisas Espaciais (INPE) [National Institute for Space Research]. A range of role players seem to be responsible for producing and mapping data. However, the desktop study did not provide much detail about the role of multiple stakeholders. Basic standards are followed: ISO/TC 211 standards, in general, including ISO 19115 for metadata; standards for web services and exchange are also in place.

Within Latin America, there is also the regional SDI, GeoSUR (La Red Geoespacial de América Latina y el Caribe).[15] GeoSUR acts as an entry point to the national SDIs of the region's countries and other geospatial portals, such as provinces, municipalities and government departments. As GeoSUR was established by the Latin American Development Bank (CAF), with the Pan American Institute of Geography and History (PAIGH) and the US Geological Survey (USGS), it also supports CAF initiatives (e.g. hydro-electric potential) and makes available the results of CAF projects. GeoSUR also generates various data sets for the whole region.

3.4 Spatial data infrastructure in Australia

Australia has been a pioneer in GIS, standards development and SDIs. The University of Melbourne has one of the premier SDI research groups in the world. Australia also has a decentralized form of government, with strong surveying and mapping organisations at the State level. However, it seems that collaboration is quite strong with one another and the federal government of Australia – and with New Zealand – within ANZLIC, the Spatial Information Council.

Australia has a central data portal[16] covering national, provincial and local governments and agencies, but the data sets are not presented in any structured or thematic form. One can browse data sets by organisation, jurisdiction, groups, tags, data formats, or licences for using the data (most are Creative Commons licences). The States also have similar portals.

In addition, Australia has an SDI driven by ANZLIC and the Office of Spatial Policy (OSP), with Geosciences Australia providing the platforms and support. The metadata catalogue, the Australian Spatial Data Directory (ASDD), has been available since 2001.[17] Core data sets include geocoded addressing, administrative boundaries, positioning, place names, land parcel and property, imagery, transport, water, elevation and depth, and land cover. A fairly large range of auxiliary data sets are provided, including themes related to Environment, Oceans, Inland Waters, Biota, Elevation, Climatology, Meteorology, Imagery, Land Cover, Health, Economy, Planning, Society, Utilities, Farming, Geoscientific, and Structures. Many and varied value-added and specialist data sets are also available. ASDD does not serve up geospatial data sets itself; however, over 20 266 records are available through the nodes providing the metadata.

In the Australian instance, another organisation, PSMA Australia

12 Can be accessed at <http://www.gov.hk/en/theme/psi/datasets/.>

13 See <http://www.inpe.br/.>

14 Can be accessed at <http://www.visualizador.inde.gov.br/>

15 See <http://www.geosur.info/geosur/>

16 See <http://data.gov.au/>

17 Can be accessed at <http://asdd.ga.gov.au/asdd/about.htm>

Ltd, also provides core data sets including administrative boundaries, features of interest, CadLite, G-NAF (addresses), land tenure, postcode boundaries, transport, and topography. Data are produced by a wide range of role players, including Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), Australian Natural Resources Data Library (ANRDL), Australian Government Department of the Environment, Australian Hydrographic Service, Royal Australian Navy, CSIRO, Geoscience Australia, Murray-Darling Basin Authority, other Commonwealth Agencies, and State governments. In the Australian instance, commercial mapping agencies such as IndexGeo (Pty) Ltd and PSMA Australia Ltd also seem prominent. A range of value-added resellers are also involved with distribution to varying extents, including 20 private-sector companies, Geoscience Australia and PSMA Australia Ltd.

Whilst implementation and funding is driven by the Australian government with both PSMA and Geoscience Australia, the dynamics of multiple role players are evident. It is interesting to note that the findings of a study commissioned during 2010/2011 to "investigate the Australian Government's current spatial capability and suggest how that capability can be improved for the benefit of the Australian public sector, private sector and the wider Australian public" (Lawrence, 2011: 5), conducted by the then Director General and Chief Executive of the Ordnance Survey of Great Britain, were rejected by PSMA Australia Ltd (a key role player in SDI and the agency that collects, packages and distributes basic geospatial data sets from its various Australian government owners [Schester, 2013: online]).

Given the complex landscape and history, a range of standards are in place. In addition to the general ISO/TC 211, OGC and ISO/IEC JTC 1/SC 24 standards, and the ANZLIC profile of ISO 19115 for metadata, standards are also in place for product specification (ISO 19131), classification (land-use codes, surveyor codes, data dictionaries for cadastre, geographical place names, bathymetry), web services and exchange.

3.5 Spatial data infrastructure in India

The history of spatial data is well established in India. The Survey of India was established in 1767 and is well known for its massive and very accurate Great Trigonometric Survey of India (begun in 1802). India was, however, slightly slow to move from analogue (paper-based) to digital mapping, for three reasons:

- The sheer size of the country.
- The high quality and detailed coverage of the analogue surveying and mapping tradition.
- Military restrictions on the availability of maps and geospatial data (e.g. contours in border areas), primarily because of the country's disputed borders with Pakistan and China.

As with China, Brazil and Australia, India has mapping and surveying organizations decentralized down to the subnational level, with 35 states and territories, 625 districts, and 5470 subdistricts. Historically, these were compartmentalised and did not readily share data and applications (Singh, 2009: 361). Consequently, the Indian National Spatial Data Infrastructure (NSDI) was envisioned only in 2001, established in 2006, and its portal launched only in 2008, with limited metadata available (Singh, 2009: 361).[18] Implementation is driven by the Indian Government and secretariat functions are provided by the Survey of India and the National Informatics Centre (NIC).

Several Indian States also have SDI agencies: Delhi, Karnataka, Kerala, North Eastern State, Madhya Pradesh and West Bengal. India only joined ISO/TC 211 in 2013 and was first represented at the 38th Plenary in Berlin, Germany, in June 2014. The NSDI has a number of collaborating agencies (for production and dissemination of data), such as the Department of Science & Technology (DST), Survey of India (SOI), Department of Space (DOS), National Remote Sensing Center (NRSC), Ministry of Earth Sciences (MoES), Geological Survey of India (GSI), National Bureau of Soil Survey and Land-Use Planning (NBSSLUP), Ministry of Home Affairs (MHA), Forest Survey of India (FSI), Ministry of Environment and Forests (MoEF), Ministry of Urban Development (MoUD), Ministry of Rural Development (MoRD), Census of India (CoI), and others. Key data producers also include organisations with specific mandates, such as the National Hydrographic Office, Central Pollution Control Board, National Disaster Management Authority and National Council for Applied Economics Research.

India has a central data portal that goes beyond merely geospatial data,[19] akin to the Australian data portal. The current version of the portal was launched in February 2014, and is an open data platform maintained by the Government of India. It is hosted by the NIC, which is part of the Department of Electronics & Information Technology in the Ministry of Communications & Information Technology. The data portal was established in collaboration with the General Service Administration (GSA) of the United States of America and has four modules, namely Data Management System (DMS), Content Management System (CMS), Visitor Relationship Management (VRM), and the Communities Module. Although access to much of the data is restricted, it is accessible to accredited stakeholders.

The objective of this general data portal[20] is to "increase transparency in the functioning of Government and also open avenues for many more innovative uses of Government Data to give different perspective". Various administrative and spatial data sets are hosted. To that effect, the portal has devised innovative means to reach out to more users of the portal to benefit from this rich resource, such as by holding competitions (e.g. #OpenDataApps Challenge,

18 See <https://nsdiindia.gov.in/nsdi/welcome.html.>

19 See <http://data.gov.in/>

20 See <http://data.gov.in/about-us>

and hackathons) to develop applications that use data from this portal, and through blogs, Facebook and Twitter. In addition, each data source has the contact details of the person responsible for the data in that specific catalogue category. It also releases a friendly monthly newsletter.[21]

Data in this portal are catalogued in various ways: by sectors (water resources, agriculture, etc.); by jurisdiction (India, State, etc.); by Ministry or Department (Planning Commission, Ministry of Water, etc.); by resource type (data set or application); by resource format (Excel, CSV, XML, HTML, ZIP, etc.) ,and by add-on (visualization or API). Metadata for limited volumes of data is available, and access to most data sets is limited to view. However, to visualize the data, there is a visualization gallery[22] in which a graphical representation of some interesting aspect of the data is presented for quick reference, which is linked to a date-line at the bottom of the page identifying when it was released.

Whilst metadata is based on ISO 19115 standards, general standards are home brewed: a content standard is used for classifying geospatial data, and exchange is regulated through national standards.

3.6 Summary of key findings

Our analysis of the selected countries shows that it takes a great deal of energy, resources, coordination and time to establish a national SDI. It is evident that the multiple stakeholder and multilayered governance environment, within which SDIs are playing a key role in terms of enhanced co-ordination, is also one of the biggest challenges in terms of implementation.

There are different levels of access to data and metadata and it seems that one of the key constraints is concern over national security. The SDIs aim at being portals to accessing the data, with the metadata stored centrally. While some geospatial data sets might be stored centrally, storing, maintaining and distributing them (such as through Web services) is primarily the responsibility of the individual data custodians (which are mainly government departments or public agencies), as they have the mandates, resources and domain expertise to do so.

The primary funding for the SDIs comes from the central government, which then enables the data sets to be available free or cheaply. The SDIs are using the standards from ISO/TC 211 and OGC. The approach being taken for SASDI is similar to that in the other countries we investigated.

As could be expected, the context, history, governance and planning system, as well as thematic issues of importance all play key roles in SDI implementation, with institutional structures, systems as well as standards and funding mechanisms critical to effective collaboration and coordination.

The Brazilian, Australian and Indian examples clearly illustrate the value of auxiliary and value-added data sets, as well as thematic classifications and integrated viewing for decision support, with accompanying challenges in terms of metadata and the need for thematic analyses and web viewers. It is also evident that effective knowledge sharing within communities and networks of practices is specifically encouraged and not merely created through standards and compliance.

4. CONCLUSIONS

The purpose of an SDI ideally has to be the effective interface between the producers and suppliers of geospatial data and those who need and utilise core data sets, as well as thematic and value-added data or information. The process is technical and, in many ways, marked by slow progress and requires many rounds of multiple stakeholder collaboration, due to a situation where a range of interdependent legal and institutional processes are underway. These include development of categories for land-use rights, finalising land-cover classes and layers, new standards for spatial frameworks and land-use management systems, etc.

Of course, a major component in this process is to assimilate the amount of often too much information into a usable and understandable form, especially for those interfacing with it from a wide range of policy perspectives and for different planning and monitoring purposes. As such, it does not suffice to have a repository of data. Besides the network bandwidth, Web services, policies and institutional arrangements making data-sharing possible, it should also be coupled with proper data-analysis tools that can be used to test various hypotheses and develop statistical models to capture the relationships between measures of interest. These could be provided by a national observatory, as envisioned by the NDP (RSA, 2012), and by theme-specific initiatives such as SAEON, the South African Risk and Vulnerability Atlas (SARVA), and StepSA. The value of auxiliary and value-added data sets is already evident within South Africa, especially given the need for indicative developmental information and data sets aimed at addressing specific developmental and interrelated aspects. The critical challenges are developing metadata sets for such thematic geospatial data sets, and the need to invest in capacity-building to enable the effective use of indicative and integrated data sets – as the mere naïve overlaying or integrating of data sets can be a danger in itself. Similarly, this is required for interpreting data sets and understanding the implications or costs of certain interventions for cities versus for households, or for the environment versus industry – especially in the South African case with the major emphasis on tracking of indicators.

It is evident that the challenge is not merely the legal and standards implementation, but also raising awareness and providing evidence of the value in collaboration, of enabling easy access and of being creative in ways to engage the wide range of role players, even the public at large. All this will enhance the value

21 See <http://data.gov.in/newsletters>

22 See <http://data.gov.in/visualization-gallery>

and understanding provided by such data sets.

Whilst more and better data and access to data are crucial to enable integrated decision-making with an understanding of systemic dynamics, the importance of distinguishing between data and analyses, on the one hand, and strategic investment decisions and sets of planned interventions requiring technical and political decision-making and visionary leadership, on the other, should not be underestimated, but rather critically supported.

Going forward, it will be essential to solicit the interest and support, not only of those involved within SASDI or with the production and dissemination of core data sets, but also of the broad range of practitioners and policymakers within the planning and development fields. In the development of SASDI, this will be critical to the success of the SPLUMA implementation, the NDP's national observatory, but even more so to effective and coordinated planning that contribute to maximum short-term impact in reaching national targets, as well as long-term environmental and economic sustainability and quality of life for future generations.

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