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SDI implementations at universities and research institutes

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1. Introduction

This article presents experiences of SDI implementations at research institutes in Chile and South Africa and at universities in the Czech Republic, the Netherlands, Poland and South Africa. Learning from this, the purpose, scope and stakeholders of the Academic SDI are described. This description is based on the formal model of an SDI developed by the International Cartographic Association (ICA) Commission on SDIs and Standards (formerly the Commission on Geoinformation Infrastructures and Standards) (Hjelmager et al. 2008).

2. The ICA's SDI model

The ICA Commission on SDI and Standards has developed a conceptual model of an SDI (Hjelmager et al. 2008, Cooper et al. 2011, Cooper et al. 2012). The model describes an SDI from different viewpoints specified in the Reference Model for Open Distributed Processing (RM-ODP) (ISO 1998). Each viewpoint provides a different abstraction of the SDI (see Table 1). To date, the Commission has described an SDI from the enterprise, information and computational viewpoint.

The enterprise viewpoint describes aspects, such as the purpose, scope and policies, of an SDI. Policies should be understood broadly to include legislation, standards, agreements, best practices and business models. The scope and policies of an SDI involve different SDI stakeholders. An SDI stakeholder can be an individual, group or organisation with an interest in the SDI achieving its purpose. SDI stakeholders either impact the SDI or are affected by the SDI (Table 2). Stakeholders define the scope and policies to meet the purpose of the SDI; they implement the SDI based on the scope and policies; and they make use of products and/or services as intended in the purpose of the SDI (Hjelmager et al. 2008).

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Table 1. Reference Model for Open Distributed Processing (RM-ODP) view points (Source: ISO 1998)

Viewpoint	Description
Enterprise viewpoint	Concerned with the purpose, scope and policies governing the activities of the specified system within the organisation of which it is a part
Information viewpoint	Concerned with the kinds of information handled by the system and constraints on the use and interpretation of that information
Computational viewpoint	Concerned with the functional decomposition of the system into a set of objects that interact at interfaces – enabling system distribution
Engineering viewpoint	Concerned with the infrastructure required to support system distribution
Technology viewpoint	Concerned with the choice of technology to support system distribution

Table 2. SDI stakeholders (Source: Hjelmager et al. 2008)

Stakeholder	Description
PolicyMaker	Sets the policy pursued by an SDI and all its stakeholders
Producer	Produces SDI data or services
Provider	Provides data or services to users throughout SDI
Broker	Brings users and providers together and assists in the negotiation of contracts between them
Value-added reseller (VAR)	Adds some new feature to an existing product or group of products, and then makes it available as a new product
EndUser	Uses the SDI for its intended purpose

The ICA's model has been used to describe a number of SDIs, e.g. Sinvula et al. (2017) present a stakeholder typology for the SDIs of Ghana, Namibia and South Africa. The typology revealed interesting similarities and differences among stakeholders.

3. Descriptions of SDI implementations at universities and research institutes

3.1 University of Twente, the Netherlands

3.1.1 Background and purpose

In 2.1, two roles for an SDI in academic *education* were described. At ITC we have tried to enable both roles, with mixed results. ITC is an institute providing education on GIS and Remote Sensing to students from all around the world, ranging from short courses to full MSc and PhD degree programmes. It was founded in 1950, and in 2016 became the *Faculty of Geo–Information Science and Earth Observation* of the *University of Twente* (The Netherlands).

Since all of our courses evolve around the use of geospatial data, an SDI to make such data searchable and accessible for the purpose of exercises, projects and thesis work would be a useful tool. An initiative was started, already back in 1999, to set up what we at the time called the *Common Database Project,* or *CDP* (Hootsmans et al, 1999). Although it was not yet named an SDI, it was set up as such for all intents and purposes, as can be seen from the setup in Fig. 1.

The purpose of the CDP was to employ and gather experience with the integrated approach to the spatial data handling process that we nowadays call SDI. It started with a focus on creating a data-rich environment for educational exercises and projects, as well as MSc-studies, with the intent to later also serve research and consulting activities. A secondary purpose was to demonstrate to the ITC faculty, as well as to the broader world of the ITC student body, (project) partners, sister institutes and alumni, the benefits of setting up and maintaining such an SDI in comparison to the (at that time) conventional ways of structuring, storing and distributing geospatial data.

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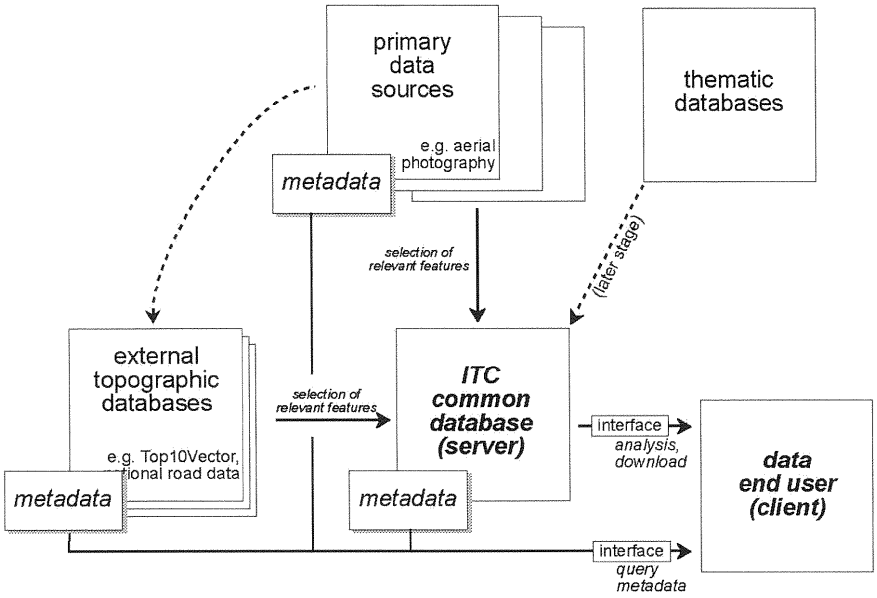

Fig. 1. Setup of the Common Database Project (CDP) (from Hootsmans et al, 1999).

The contents of the CDP were focused on topographical or framework data, the common set of base data of areas of study, usable for the wide range of spatial applications that our students and researchers are involved in. We started with the data-rich environment of the municipality of Enschede (a medium-sized city in the Netherlands where the institute is located), with the view of later moving to relatively data-poor examples of the developing countries where most of our students come from.

3.1.2 Stakeholders

The project was an initiative of the (then four) departments in ITC that deal with the methodological and computer-engineering side of geo-information. A four-person steering group started the project and was responsible for the management and organisational embedding, and as such can be labeled as the *PolicyMakers*. In light of the nature of the data content described above, the data *Producers* were to a large extent (National) Mapping and Cadastral Agencies, but ITC staff were also data *Producers*, because geospatial data is produced in many of our research and consultancy projects. The role of *Broker* was never really identified. This is also true for the *VAR* role, although with hindsight one can reason this role was present, because the students and researchers that used the CDP in many cases added value by further developing data and products based on what they retrieved from the CDP. Other people who would use these products (e.g. in the following years of MSc-projects) or the original data directly can be considered as *EndUsers*. It has to be noted however, that none of these roles were ever described or made explicit as such, in any stage of the project.

3.1.3 Lessons learned

As an institute-wide SDI, the CDP has never really taken of, most of its ambitions were not realized and after a few years the initiative had slowly faded away. This, we think, is foremost because the *PolicyMakers* group was mostly interested in the technological side and did not manage to identify, let only activate, the main stakeholders, especially the *EndUsers*. As a result, they were not actively involved and showed little interest in what at the time to them was a novel, unproven and unusual way of working with geospatial data. Furthermore, the technology of SDI was still in its infancy, and especially standardization was mostly lacking, e.g. the WMS 1.0.0 standard was not published until a year later (OGC, 2010). Probably, the CDP came a little too early to be successful.

On the other hand, when considering the CDP as a *learning tool*, it was certainly a success. It gave ITC staff early and hands-on exposure to the technology and organisational aspects of SDI. In our experience, this has greatly helped integrating SDI technology in our study programmes, where nowadays we implement what we have called the SDI^{light} concept, described in Köbben et al. (2010). In

short, it comes down to applying the principles of SDI, using open standards whenever available and open source solutions where possible, which is of particular interest to ITC students, who mainly come from developing countries. By integrating this approach in all our teaching, students use, and build SDIs throughout the courses. In this way, the SDI serves as a subject of study, as well as a realistic working environment.

3.2 University of Groningen, the Netherlands

3.2.1 Background and purpose

Geodienst is a spatial expertise group of around 20 employees, within the central IT department of the University of Groningen. Working with partners like Oxford university, NWO groot, SER, LifeLines, local governments and almost all faculties of the university. *'Enabling better research through the use of spatial information'* is our mission. We believe that in order to reach our goals we need both spatial expertise, communication and management skills. In contrast to our current success, two and a half years ago this group was almost abandoned and consisted of only one person.

The SDI plays an important role as a tool, but is not seen as a goal in itself. Our goal is supporting our institution with the best geospatial expertise possible. Subsequently, we take a process oriented approach rather than a functional approach. In order to do this, we made a change from solely buying and serving data towards creating and harvesting data and advising researchers. It is a prerequisite that the SDI functions technically, but we consider the promotion of the added value of geospatial information in all kinds of research and processes the key to success.

Our SDI works in the following way: everyone at the university can login via' single sign-on' to the online AGOL-based GIS environment and search for and download data. There is an open data portal linked to the same infrastructure. A real time etl tool is used to feed some of the datasets from external sources. Desktop GIS (QGIS and ArcMAP) are available at every workplace. Most data is stored in an Oracle database.

3.2.2 Stakeholders

Key stakeholders are researchers, teachers, students and non-scientific staff (e.g. real estate management). They are actively approached and continuously informed about the current possibilities of GIS. *Geodienst* is not just responsible for managing the SDI, but also for promoting the use of geospatial information across disciplines. This includes traditional domains such as the spatial sciences and archaeology, as well as economics, history, medicine, sociology, psychology, natural sciences and engineering. This nondiscriminating promotion of the SDI gives us what we call 'deep resonance', within and outside of our institution. It is important that the boss and decision makers (*PolicyMakers*) are convinced of our value, but what better way to show that than with a big portfolio of a diverse range of happy clients?

The organisational structure of *Geodienst* is flat, one senior project manager is in charge of the team, acquisition and strategy, and one coordinator is in charge of organizing support and technical maintenance. Projects have a project leader who falls directly under the senior project manager. It is the role of the senior project manager to promote the use of geospatial data across the university. Calls and follow up questions from these sessions are passed to the support team, which is largely manned by students. More complex questions are forwarded to the second line or become projects. The general approach towards challenges is very pragmatic. In this way, *Geodienst* works like a startup. Student assistants are seen as regular employees and originate from faculties such as Spatial Sciences, Arts (Archaeology and Landscape History) and Artificial Intelligence. This keeps costs down and the innovation rate high, although a certain level of chaos is perhaps unavoidable.

3.2.3 Lessons learned

An SDI is part of a larger theme like facilitating scientific research, which involves not only the hard- and software but also GIS-expertise and communication. So counterintuitively, we believe that focussing on SDI itself is not the key to a successful SDI implementation. Focus on the biggest constraint to your goal and sink your teeth in that, whether it is obstinate management, lack of expertise or political approval from different stakeholders.

Key lessons learned in Groningen are that in order to have the biggest chance of reaching one's goal, one has to focus one's energy on the biggest constraint hindering that goal. Further, we (nobody else) are responsible for selling our ideas. Students are capabel of handling responsibilities.

Early in 2014, the *Geodienst* had two employees and very few users. To change the decline they hired student assistants (there was no funding for experienced personnel) and started promotion activities across the institution. The mandate for the team was simple: go out and promote geo! The project manager gave over 200 talks in the first year, getting as many people excited about geospatial information as possible. *Geodienst* didn't ask for money for their services but focussed solely on, *how to help you with spatial information*. Any follow up questions where immediately passed to the team wo immedialtely started working on them.

Armed with a list of more than 100 happy scientists and a few teachers as well, we took the next big step, asking for structural funding. Our strategy was simple: present the results to management and a delegation of the faculties and ask: 'Since we only have a temporary budget, how do you propose we continue?' We were fortunate to have a strong case and enough political goodwill. The decision for (modest) permanent funding was almost unanimous. Within two years *Geodienst* built a great portfolio of use cases on a limited budget.

3.3 VSB - Technical University of Ostrava, Czechia

3.3.1 Background and purpose

The Institute of Geoinformatics, VSB – Technical University of Ostrava (VSB-TUO), Czechia, participated in development and deployment of the meta-information system, MIDAS (MetaInformation Database System) (Pauknerova et al. 2002), which was established, among others, as a pilot meta-information system of public administration. When it was active, the pilot system contained metadata of approx. 3500 geospatial datasets, but also supported collecting metadata of services, events, projects and application software.

The research and educational teams of several faculties of VSB-TUO work intensively with geospatial data, e.g. the Faculty of Mining and Geology, the Faculty of Civil Engineering, the Faculty of Metallurgy and Materials Engineering and the Faculty of Safety Engineering. They use either external data (which are usually licensed to the whole VSB-TUO), or data collected by themselves during research activities or teaching. Both data categories can usually be of interest to other research or educational groups, but there is no central register of such data that could support sharing these. A similar situation exists with specialized software for geospatial data processing. This is why the Institute of Geoinformatics addressed other groups across the university with the offer to establish a meta-information system for VSB-TUO covering geospatial data and software, either licensed or self-collected and/or developed. The meta-information system had to be developed on the basis of MIDAS with the aim of becoming the foundation of the university's infrastructure for geospatial data and services.

The original idea was to use the MIDAS meta-information system for registering any geospatial data set or spatial processing software, either bought or self-collected or developed. For the future, it was planned to register developed geoprocessing services and to develop some central storage for all geospatial data, which could support sharing with people either inside or outside the university.

3.3.2 Stakeholders

A basic set of interested stakeholders were identified at the onset of the project: research and educational groups, researchers and students. On the basis of this consideration the first discussions were started about ten years ago with unofficial representatives from each of the above-mentioned

faculties, usually members of research and educational groups. The aim was to convince them of the usefulness of such meta-information system. At the time, a few Diploma theses focused on this topic, but nothing was ever fully implemented as a widely usable service. Unfortunately, the representatives could not be convinced of the usefulness of this system, and eventually it was decided to terminate the project.

3.3.3 Lessons learned

The reasons why the process of establishing an SDI failed can be summarized as follows:

- no awareness of the importance of any data (not only geospatial data) at the university level and the consequent absence of the university policies in this area;
- concerns of faculties and research and educational teams that they would have to participate in financing the operation of the meta-information system and the central data storage;
- reluctance to share data; and
- fear of losing control over datasets when they are stored centrally.

The first point is probably the most important: unless one does not increase awareness of the value of the (geospatial) data, and/or if general university policies on data are not introduced, then one cannot expect the successful introduction of the Academic SDI at VSB-TUO. Therefore, the role of *PolicyMaker* stakeholder is perceived as the most important by members of the Institute of Geoinformatics. Without a clearly defined common policy it is impossible to create a university wide Academic SDI. Such an SDI could be established easily for a single research or educational group, lab, or department, but such an approach would defeat the fundamental ideas behind an SDI.

3.4 CSIR, South Africa

3.4.1 Background and purpose

Established in 1945, the CSIR is a public science council, governed by an Act of the South African Parliament. It is the largest multi-disciplinary scientific and industrial research organisation in Africa. The CSIR operates through a number of business units that are largely independent. The CSIR is not the custodian of any base geospatial data sets, but does contribute in various ways to base geospatial data sets of several custodians. The CSIR has a basic SDI internally for making base geospatial data available. However, there is very little sharing of geospatial data across business units outside of projects, because of commercial sensitivities, protecting personal data, and military and other secrets, such as crime mapping for the police investigations. Because costs are incurred at the lowest level in the organisation, it is in any case difficult to establish large and expensive organisation-wide systems such as a comprehensive SDI.

3.4.2 Stakeholders

In terms of the SDI stakeholders, the *PolicyMakers* are the same as for other functions or operations within the CSIR, namely those in all levels of management. Specifically, the executive levels set the overall policies and allocate the limited general research funding made available by the Parliament to the CSIR. At the operational levels, the SDI-related policies and funding depend on the projects. The *EndUsers* vary from naive to expert, to the extent that some *EndUsers* source and maintain themselves all their data. The remaining four types of stakeholders are essentially absent from the CSIR, because of the narrow project and client focus of all geospatial data sets created by the CSIR.

3.5 Research Centre for Sustainable Urban Development (CEDEUS), Chile

3.5.1 Background and purpose

The CEDEUS research centre, founded in 2013, unites university researchers that work on different aspects of urban development, e.g. use of natural resources, transport and mobility, built environment and social segregation. The objectives are to exchange knowledge among researchers of the different disciplines; to encourage inter-disciplinary research; to monitor urban development; and finally, to suggest public policies that improve the quality of life of the population while keeping resource consumption and environmental effect low. Approximately 40 researchers, i.e. university professors, are in the centre's research team. In addition, a further 30 postdocs, thesis students and technical or research staff are part of CEDEUS.

The CEDEUS SDI was funded to support the mentioned centre goals in the form of a service unit. That is, the SDI and its team should (a) provide a 'drop box' and catalogue of geospatial data, with the intention to distribute much needed base data and share data produced during research; and (b) to train and support students and researchers that are not familiar with GIS and mapping technologies.

The range of data available is quite diverse. While the data core consists of geospatial datasets (vector and raster data), a huge portion of data and information are documents (such as municipal developments plans in the form of text and plans) in PDF and DOC formats, spreadsheets, as well as maps and graphics stored in generic image formats. To access, store and manage the data and documents the free software platform GeoNode[1] is used.

3.5.2 Stakeholders

The CEDEUS SDI policy distinguishes only three stakeholders with respect to access to data. These three are: the GIS/SDI team, researchers, and the public. The *PolicyMakers* are a small group: policies are proposed by the GIS/SDI team and discussed and agreed to by the centre's board of directors (i.e. principal investigators). The GIS/SDI team is the only *Producer* of services. There are many data *Producers*, including the GIS/SDI team, researchers, and also 'external sources', such as governmental authorities (i.e. ministries) and other research centres or universities. The GIS/SDI team is the only *Provider* of data and services (at the moment). The original intentions were that all (40) CEDEUS researchers and technical staff would be *Providers*. The *Broker* role is taken on by the GIS/SDI team, i.e. only the SDI core team members harvest metadata or create catalogue entries. While there were initial thoughts about *VARs*, this type of stakeholder is not considered at the moment in the CEDEUS SDI structure. However, we have a centre initiative that uses the SDI data to calculate sustainability indicators for cities. These products (i.e. the indicators) are not for sale, they are made available as must-have 'products' for a publicly funded research centre on urban research. Finally, the *EndUsers* of the CEDEUS SDI are manifold: mainly (thesis) students, postdocs, a small portion of centre and external researchers and educators, but most importantly, also the public.

3.5.3 Lessons learned

After about three years of existence it is difficult to speak of a success story, but also the SDI is definitively not a failure. While the initial user focus was on the CEDEUS researchers – the usually tenured professor – it turned out that this group is fairly resistant to learn and use the SDI. However, on the demand side, the group of thesis students that use the SDI to search and download data is growing. Unexpectedly, some documents (i.e. municipal development plans from some municipalities) experience demand from the public, most likely because some municipalities have not made these documents available online. Also increasingly external researchers and students are visiting the SDI webpage due to word of mouth, the use of twitter, and conference presentations. On the data provision side, at the moment only two external entities have contacted us with the wish to provide data, and approx. three (of the 40) researchers have provided research data. However, apart from reaching out via social networks, introductory GIS workshops for students helped to spread the word. A further key

[1] www.GeoNode.org

factor has been the indexing of the SDI content by Google's Search engine, which brings users from the public to the site. In summary, the success with respect to the data demand-side has shown to depend on two factors: (a) attractive data (i.e. focused on certain users and their demand); and (b) public relation strategies to make the SDI known to others. From a data exchange perspective, i.e. researchers sharing their data, the SDI has not reached its objective yet and it is a bit unclear how this can be encouraged, as the country's (research) culture with a strong thinking of 'data ownership = research advantage' plays a strong role here.

3.6 University of the Witwatersrand (Wits), Johannesburg, South Africa

3.6.1 Background and purpose

The GIS and remote sensing group is a multi-disciplinary teaching and research group with researchers across Wits who develop and use GIS and remote sensing for teaching and research. Group members' fields of expertise include: geography, archaeology, environmental studies, geosciences, statistics, computational sciences, engineering, health and social sciences. The group of approx. 20 members (lecturers, researchers and IT professionals) produces a range of freely available services, tools and datasets for spatio-temporal analysis. In 2013, the group initiated a project of constructing a Spatial Geodatabase and also expressed the need for a university based server that can meet the needs of the wider group of users across campus. Available data include satellite imagery, topographical data, land cover, land use, administrative or political boundaries and relevant value data (obtained as output from research work). Plans for the design and creation of a Web-GIS platform for data sharing are currently being contemplated.

3.6.2 Stakeholders

The initiative is driven by a group of academics who meet at least once a month to discuss policy, technology (software, hardware and data), standard procedures and research necessary for promoting the idea of having an SDI for the benefit of the University community. The various resolutions and decisions adopted by the group need to be passed through the School of Geography, Archeology and Environmental Studies (GAES) for approval, i.e. GAES is the *PolicyMaker*.

The GIS and remote sensing group champions the initiative and also plays the role of secretariat for the initiative. The data *Providers* are GAES, the Gauteng City-Region Observatory (GCRO) and other departments, schools and research units or centres that are members of the GIS and remote sensing group. The latter may also act as *VARs*. Various members of the group besides GAES (e.g. the GCRO) also make web services (e.g. map web services) available to University students, academics and the public in general. They are the service *Providers*. Research units or centres (e.g. GCRO and other group members) have other sources of funding and perform their activities independently from GAES. *EndUsers* include students, academic staff, group members and the general public (some members of the group make data and/or their services available to the public).

3.6.3 Lessons learned

To date, the GIS and remote sensing group does not have any officially status at Wits, because it is still in its infancy even though the initiative started three years ago. Nevertheless, the group enjoys the enthusiasm among its members who continue to increase in numbers. There is currently no buy-in from the Department of Geography and the School of Geography, Archeology and Environmental Studies to support the efforts of the GIS and remote sensing group, even though the Chair of the group is affiliated with GAES. This sometimes translates into rejections of requests for funding necessary to materialise the activities of the group, such as the acquisition of hardware to store old and new geospatial data, and software necessary to support an SDI at Wits.

3.7 Academic Geo Hub Platform, Wroclaw University of Environmental and Life Sciences (Poland)

3.7.1 Background and purpose

In the context of a number of ongoing research projects and educational activities conducted at many universities in Poland, much geo-reference data is produced. Due to the distributed nature of the data collected by independent entities, access to them is very limited.

The need to create a common platform for the exchange and sharing of geospatial data for scientists has been the subject of interest of the PL-Grid Consortium, which has taken up the work on the preparation of dedicated, domain-specific computing services for new groups of researchers. Established in 2015, the Academic Geo Hub Platform is part of the PLGrid NG project ('New generation domain-specific services in the PL-Grid Infrastructure for Polish Science', 2014-2015) carried out by the PL-Grid Consortium.

In Poland, researchers have free access to geospatial data collected by public administrations (access is much wider than for the citizens). However, it requires going through complicated administrative procedures. The main objective of the PL-Grid Infrastructure is to provide a solution that allows access and exchange of geospatial to Polish scienctists in order to strengthen collaboration among researchers.

Today, the Academic Geo Hub is a repository of geospatial data for academics. It acts as a science laboratory combined with a social networking service. Using an intuitive web interface, users can transfer data and manage access to them, deciding to protect them or provide access to any other scientists for further analysis. This solution supports collaboration among research teams.

The platform is built on open source components (i.e. GeoNode, PostGIS) together with a proprietaty product, AllegroGraph, a repository of RDF triples. It allows searching, downloading and publishing of geospatial data, as well as integration with other resources. Graph representation of the metadata makes it easier to keep track of which of the available databases are most commonly used or if any new resources appear which are based on previously published data.

Maps created in the platform may be publicly available. Each dataset or map composition has its own unique URI, which allows for its citation. This is especially beneficial for young researchers who have obtained partial results, not yet published in journals.

3.7.2 Stakeholders

The academic community, including both researchers and students, is the targeted *EndUser* of the platform, as well as the *Producer*. In the group of suppliers we can also distinguish public administration, which we contacted during the project. Unfortunately, only few public entities agreed to share their data for the project, which shows that there is still limited awareness of the open data idea. Due to the short time of operation of the platform, it is still difficult to predict its future development. Certainly, at the moment it requires effective promotion and popularization of solutions among scientists. It is not a coincidence that the idea of open data in public administration has evolved considerably since the launch of the platform. Perhaps it is reasonable at this moment to take further steps to re-establish cooperation with the public administration.

3.7.3 Lessons learned

The main difficulty in the functioning of the platform is the lack of a business model and public policies. SDI in the administration develops through new laws enforcing certain actions, standards, rights and obligations. Sources of financing and responsible entities have to be indicated in the regulations. SDI development in the area of business is conditioned by business models of individual stakeholders. In the area of science, both factors have a limited impact on the construction of infrastructure. This causes a situation where the taken efforts have limited impact and are difficult to maintain in the long term if no permanent financing is provided for the development and maintenance.

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Acknowledgements

Stefan Steiniger is grateful for funding by Conicyt (Conicyt/Fondap/15110020 and Conicyt/Fondecyt/1150239). Samy Katumba would like to acknowledge the assistance and cooperation of Dr. Stefania Merlo, Chair of the GIS and remote sensing group at the University of the Witwatersrand, South Africa.

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