

# Free and Open Source Software for Geospatial (FOSS4G) Conference Proceedings

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Volume 13 *Nottingham, UK*

Article 3

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2013

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Raul Fernando Molina Rodriguez

*GeoBolivia, Bolivia*

Sylvain Lesage

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### Recommended Citation

Molina Rodriguez, Raul Fernando and Lesage, Sylvain (2013) "Spatial Data Infrastructure of the Plurinational State of Bolivia - A free and democratic SDI," *Free and Open Source Software for Geospatial (FOSS4G) Conference Proceedings*: Vol. 13 , Article 3.

DOI: <https://doi.org/10.7275/R50Z71GJ>

Available at: <https://scholarworks.umass.edu/foss4g/vol13/iss1/3>

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# Spatial Data Infrastructure of the Plurinational State of Bolivia

## A free and democratic SDI

by Raul Fernando Molina Rodriguez and Sylvain Lesage

GeoBolivia (Bolivia). [rmolina@geo.gob.bo](mailto:rmolina@geo.gob.bo)

## Abstract

The Vice Presidency of the State, with the help of the GeoBolivia project, is building the Spatial Data Infrastructure of the Plurinational State of Bolivia (IDE-EPB by its Spanish initials). The first phase of the project has already been completed. It consisted in implementing an infrastructure and a geoportal that nowadays gives access to the reference geographic information of Bolivia, through WMS, WFS, WCS and CSW services. The project is currently in its second phase dedicated to decentralizing the structure of IDE-EPB and promoting its use throughout the Bolivian State.

The whole platform uses free software and open standards. As a complement, an on-line training module was developed to undertake the transfer of the knowledge the project generated. The main software components used in the SDI are: gvSIG, QGIS, uDig as GIS desktop clients; PostgreSQL and PostGIS as geographic database management system; geOrchestra as a framework containing the GeoServer map server, the GeoNetwork catalog server and the OpenLayers and Mapfish GIS webclient; MapServer as a map server for generating OpenStreetMap tiles; Debian as operating system; Apache and Tomcat as web servers.

**Keywords:** SDI, Bolivia, GIS, free software, catalog, gvSIG, QGIS, uDig, geOrchestra, OpenLayers, Mapfish, GeoNetwork, MapServer, GeoServer, OGC, WFS, WMS, WCS, CSW, WMC.

## Introduction

The Spatial Data Infrastructure (SDI) of the Plurinational State of Bolivia IDE-EPB, created through the GeoBolivia project, aims at providing useful geographic information (GI) to institutions and citizen. The SDI provides relevant, harmonized, and high

quality GI, allowing to support the formulation, evaluation, implementation and monitoring of practical policies, with a direct or indirect impact on the territory. Additionally the SDI brings support in terms of education and research.

The GeoBolivia project is responsible of organizing the cooperation with and between all the institutions involved in the field of GI in Bolivia. Indeed, the contribution of public and private institutions and professionals is crucial for strengthening and improving the data.

With respect to these main objectives, the specific goals of the first phase of the GeoBolivia project were to build a server infrastructure, publish GI using open standards<sup>1</sup> and develop a web portal for consultation, as a pioneer and main node of the SDI (Nebert, 2004).

Regarding the selection of technology, the GeoBolivia project opted for the use of free software and OGC standards, ensuring its sustainability and promoting the democratization of access to information. On one side, this decision was based on the conviction that democracy depends on an informed citizenry with a wide access to public information, allowing them to fully participate in public life, collaborate in determining priorities for public spending and fight against corruption through demand accountability (Neuman, 2002). On the other side, the selection of free software was based on the fact that open source geographic software has reached yet a mature technological level that allows to use them exclusively. The use of free software is also endorsed by Article 77 of the new Bolivian General Telecommunications Law that states: "The Executive, Legislative, Judicial and Electoral bodies at all levels shall promote and prioritize the use of free software and open standards, within the framework of sovereignty and national security".

## Project Development

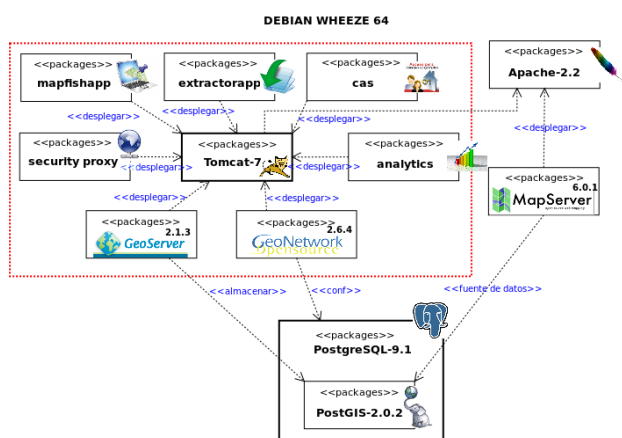
### Main SDI framework

Initially, various technological options for imple-

<sup>1</sup>The only exception to the rule of open standards is the use of ISO 19139 profile for metadata (see <http://www.opengeospatial.org/ogc/faq/openness/#2> for definition of an "open standard"). It has been decided the benefits in terms of interoperability of using this *de facto* standard justify the exception.

menting the framework of the IDE-EPB have been evaluated, giving priority to free software, modular architecture and community development. In this sense the following solutions were considered: GeoNode (<http://geonode.org/>), EasySDI (<http://www.easysdi.org/>) and finally geOrchestra (<http://www.georchestra.org/>). Although the basic software modules of the three solutions are the same (GeoNetwork and GeoServer), the latter has been chosen principally for its independence to any leading company or international institution, and for the better functionalities of its map viewer module.

## Complete software architecture



The IDE-EPB software architecture is based on geOrchestra for the management of GI, but also includes other components for all side infrastructure. In every part of the project, free software is exclusively used.

All desktop and laptop computers are using distributions based on Linux. FOSS GIS clients (QGIS, uDig and gvSIG) are used for data processing before storage (encoding, projection, conversion) and creation of styles and symbols for WMS maps. Some functions of the GDAL library are directly used for raster conversion.

The servers use GNU/Linux operating system (Debian Wheezy), Apache2 as a proxy and web server and Apache Tomcat as a Java applications server to deploy the geOrchestra modules.

The geographic components of the SDI, based on geOrchestra modules, are the following:

- A repository of geographic files (SHP and Geo-

<sup>2</sup>As mentioned in the OpenStreetMap wiki, "OpenStreetMap data is free for everyone to use. Our tile servers are not." The IDE-EPB decided to generate its own tiles in order to contribute to the distribution of OpenStreetMap base maps of Bolivia, instead of penalizing community servers by just using their WMS services. See [http://wiki.openstreetmap.org/wiki/Tile\\_usage\\_policy](http://wiki.openstreetmap.org/wiki/Tile_usage_policy).

<sup>3</sup><http://www.spip.net/>

TIFF formats).

- A geographic database (PostgreSQL and PostGIS).
- A map server for generating web services (GeoServer).
- A metadata catalog linked to the web services (GeoNetwork).
- A map viewer with basic GIS client functionalities (Mapfish, based on OpenLayers).
- An extractor, related to the map viewer, for downloading at once various layers of data for a given geographic extent (Extractorapp).
- A map server dedicated to the generation of base maps using OpenStreetMap data<sup>2</sup> (MapServer).
- A central authentication system (CAS), a security proxy and a LDAP users directory, providing shared rights management between all modules.
- An analytics module for monitoring the use of web services.

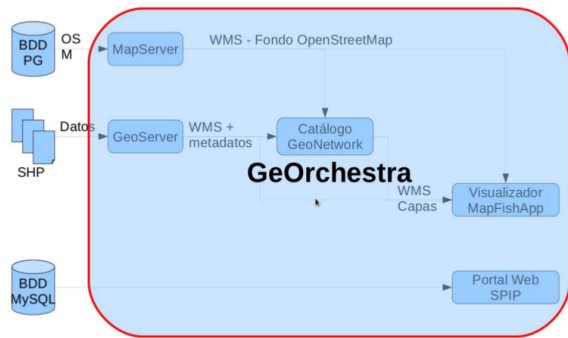
Moreover, the website and the blog are based on the SPIP content management system<sup>3</sup>, documentation and project management are managed by Chiliproject (<https://www.chiliproject.org/>), and the knowledge transfer systems are Moodle (<https://moodle.org/>) for on-line training and OpenMeetings (<http://openmeetings.apache.org/>) for web conferences.

## Cycles of development

The SDI implementation was realized following cycles of development, beginning with an initial prototype, and improving it through new versions regularly published in 2012 and 2013. Five versions were published:

Version 0.1: Prototype platform with a simplified installation of geOrchestra and a simple website;

Version 0.2: Installation of the main modules of geOrchestra (map server, catalog, user management), generation of a WMS base map using OpenStreetMap data, update of the website;



Version 0.3: Installation of a geOrchestra auxiliary module (extractor allowing data download), development of an "API" which enables users to display GeoBolivia data on their own website, new website presentation with a large section providing texts, images and videos dedicated to help users;

Version 0.4: Two SDI nodes (IDE-EPB node and risks management node) interconnected via catalog harvesting (CSW) and maps services (WMS), installation of an auxiliary module of geOrchestra (simple web catalog client), map viewer for mobile devices, Live DVD (based on Ubuntu 12.10) containing all main GeoBolivia data, metadata and styles, and free GIS client tools;

Version 1.0: Creation of "virtual nodes" for institutional partners, hosted on GeoBolivia servers, with remote access and rights to upload, edit and publish their own data, higher level servers infrastructure, with an increased control on the availability of services and data quality.

The following versions are intended to include:

- more contributions to the geOrchestra community and development,
- a webpage for direct download of full datasets,
- community assessment on data and metadata quality, with a comments and ratings system,
- a personal space for every user,
- interconnection with generic opendata catalogs.

## Interactions with the geOrchestra community

As a reciprocity to the use of the geOrchestra framework, the GeoBolivia team became an active member of the community by contributing to improvements

<sup>4</sup>geOrchestra is now available in English, Spanish and French.

as for example the internationalization of various modules<sup>4</sup> and animating the community forums. As a result of these interactions, the version 12.11 of geOrchestra (<http://blog.georchestra.org/post/2012/12/16/geOrchestra-12.11-Bolivia-is-out>) was called "Bolivia", and geOrchestra was given a logo representing a condor, the main symbol of the Andean countries. Moreover, various meetings were organized, in Bolivia and France, between the GeoBolivia project team and members of the French community.

## Functionalities of the portal

The detailed functionalities of the GeoBolivia portal are the following:

### • Map viewer

- Movement, zoom on the map.
- Add new layers from the catalog or a remote WMS.
- Change and save the style of a local or remote WMS layer.
- Query a layer and filter the data displayed.
- Save or restore a list of layers using Web Map Context (WMC) files.
- Print a map in PDF format.
- Display global coordinates (EPSG 4326).

### • Catalog

- ISO 19139 metadata profile.
- Allow to harvest metadata records on distant catalogs.
- Allow distant catalogs to harvest the GeoBolivia metadata records.

### • Extractor

- Possibility to choose an area of extraction.
- Handle of various export formats (ECW, GeoTIFF, SHP).
- Rights access management.
- Sending an email when extraction is complete.

### • GeoPublisher

- Allows publishing geographic data from the GeoNetwork catalog, after loading the data in the metadata record.

## Workflow of data publication

One of the tasks of the GeoBolivia project has been to collect, order and publish GI. The first step was to inventory the existing GI generated or owned by the State. Then, data were formally requested to all public institutions, under the premise that all information generated from State resources must be public and shared. The requested format for vectorial data is Shapefile (.shp) and GeoTIFF for raster data. In case of receiving GI under another format, files are converted using QGIS, gvSIG, uDig or in case of raster conversion, a GDAL library function is used.

Some processing is done using uDig or QGIS in order to check the topology, projection and attributes of the data. Once processed, the GI (vectorial or raster) is stored on the server and published after a step of configuration of the OGC services. Those web services are organized by namespace in the map server, using the name of the GI producer<sup>5</sup>.

Each layer is assigned a style (SLD), generally created with the producer of the GI using uDig, in order to display the maps (WMS) with a meaningful symbology.

Finally, an ISO 19139 metadata record is stored in GeoNetwork and linked to the OGC services metadata (WMS, WFS).

## Phase I: technological platform and first interactions

The main objective of the GeoBolivia project, in its first phase, is to standardize, and distribute GIS democratize the Plurinational State of Bolivia.

In this sense, a strong emphasis was done on the technological implementation: install and configure a metadata catalog (<http://geo.gob.bo/geonetwork/>), store, organize and publish data and services (<http://geo.gob.bo/geoserver/>), create a central access point to Bolivian GI with a web portal, that links to the viewer, download and catalog client modules (<http://geo.gob.bo/>). In a spirit of transparency of the project process, a shared development platform was installed, enabling to document the entire project development in a systematic and ordered way (<http://intranet.geo.gob.bo/proyectos/>).

Similarly, it is important to note that during the first phase began an institutional coordination, through activities with users and providers of data within the Inter-institutional Committee.

Four meetings of this committee were organized in 2012 and 2013, achieving the composition of its members, interactions around the first developments of the IDE-EPB, and the redaction of a draft of Supreme Decree and Regulations for the constitution of this committee. The main objectives of the Inter-institutional Committee (<https://geo.gob.bo/?-El-Comite-Interinstitucional->) are to define working directions based on the requirements of its members and to define rules and bring support for GI production and publication, in order to foster the interoperability of the information within the State.

As another part of the project, a virtual learning module (<http://geo.gob.bo/cursos/>) has been developed with the purpose of training the users and producers to apprehend new geographic technologies and adopt the IDE-EPB in their workflows.

The GeoBolivia project also promoted the elaboration of Bolivian standards regarding the handling of GI, within a working group composed of public institutions and headed by the Bolivian Institute of Standardization and Quality (IBNORCA). The spirit of the redaction of these standards is to adapt and simplify the ISO:19100 norms, in order to fit the Bolivian reality.

An important element of the GeoBolivia strategy is the nodal vision, that aims at organizing the SDI as a network of thematic or hierarchic nodes, responsible for its own part of the national data, and linked together using web services (OGC). This should provide technical and organizational robustness and sustainability to the SDI. Therefore, in order to facilitate the implementation of new nodes, the GeoBolivia project is working on a Live DVD offering not only a copy of the GeoBolivia database, but also the ability to install all the software applications that GeoBolivia infrastructure uses. It will include geOrchestra in its internationalized version, allowing to replicate the functionalities of GeoBolivia on any institutional server. Nevertheless, the nodes are free to use any other solution, under condition of giving access to the GI through OGC standards. For example, the first thematic node directly integrated to the IDE-EPB nodal architecture (the GeoSinager portal (<http://geosinager.defensacivil.gob.bo/>), dedicated to "risks management") uses the GeoNode SDI framework without the need of any adaptation.

At the end of the first phase of the GeoBolivia project, the IDE-EPB is still mainly centralized, play-

<sup>5</sup>For example, maps generated with GI from the Department of Education are published in a WMS service accessible at <http://geo.gob.bo/geoserver/mde/wms> ("mde" is for "Ministerio de Educación")

ing the role of repository of all the GI recollected from State institutions and giving free access to it with the appropriate metadata.

## Phase II: a public SDI, shared and financially sustainable

Whereas the proposal of the first phase of the GeoBolivia project was only to build a central node for managing State GI, the second phase aims at decentralizing the architecture of the IDE-EPB, recycling existing systems and integrating new platforms into a nodal structure. The SDI is intended to evolve from the current structure implemented in the IDE-EPB (a group of servers located in the Vice Presidency) to a nodal structure (multiple servers interconnected among several institutions). This involves articulation and enhancement of thematic information systems which already exist in other institutions. Most of them were the result of much effort and budget, and even if these systems are mostly not SDI nodes, but rather closed systems only dedicated to data consultation, they may be converted into node catalogs of the IDE-EPB.

In the desired nodal structure, the nodes are interconnected, and possibly replicated, using OGC web-services, providing access to all the State GI to the clients independently of the node they consult. The hoped benefits of such an organization are a better robustness to technical or institutional<sup>6</sup> failures, where the loss of a node does not impact strongly the whole structure, and a more precise control of the quality of data thanks to the splitting of GI into expertise thematic nodes.

Another structural challenge to address in the second phase is the integration of GI from players who do not have the resources or technology to build a node, allowing them to manage their data directly in the central node. Such actors may be territorial subdivisions governments, or institutions that only produce few specific data such as the location of thematic infrastructures (banks, schools, projects). To do this, the GeoBolivia project has developed guidelines and tools to allow the creation of GI and also promotes GI exchange protocols to ensure interoperability through standards. This means that each institution according to its competence may create and update remotely its own metadata and data without

the need of operating a node by themselves.

In the same goal of associating State actors to the IDE-EPB, the GeoBolivia project will develop a strategy of participatory quality control of information, facilitating the integration of comments and evaluations by data users directly in the metadata catalog and creating a consultative commission of users and providers, that could emit recommendations to the Inter-institutional Committee.

Institutional progress is essential to carry out any project of SDI. The GeoBolivia project in its second phase is promoting the socialization and coordination with various institutions conducting to strengthening the links established with the main entities producing GI in Bolivia, such as: the Military Geographic Institute (IGM), Unique System of Earth Information (SUNIT), National System of Risks Management (SINAGER) and the National Institute of Statistics (INE), since they cover almost sixty percents of Bolivian State data, and therefore their active participation is required for the Inter-institutional Committee.

Furthermore, the close collaboration with international entities such as the University of Geneva, GéoBretagne, geOrchestra, GeoNode and international cooperation will be promoted in order to foster academic activities and specific programming developments, and to coordinate tasks in regard to the management of GI. The inclusion of the Bolivian universities within the activities of the GeoBolivia project will continue similarly to the first phase, offering internships, promoting the use of open standards and encouraging the generation of new information technology. Currently the GeoBolivia project works with the various universities such as UMSA (La Paz), UPEA (El Alto), UATF (Potosí), UMSS (Cochabamba), USFX (Chuquisaca) and UAGRM (Santa Cruz). The second phase will focus on support for the training of new professionals in the area of SDIs.

## Conclusions

Whereas the GeoBolivia project is still in progress, some lessons have already been learned, helping to better focus the future efforts. The main experience has been to understand that building a SDI is basically an organizational challenge, in which the technological implementation covers less impor-

<sup>6</sup>As described in Rodríguez-Carmona 2009, a strong tendency in the past thirty years in Bolivia has been to rule the State using a logic of projects, without a general political vision, leading to duplication of efforts and discontinuity in funding. This paradigm is still present in various emerging SDI nodes in Bolivia, but the decentralized structure is conceived to integrate these fragile projects and their data without endangering the whole organization.

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tance than the correct comprehension of the social reality of the actors that compose the State.

The IDE-EPB aims at improving the quality of GI circulation within and between institutions of the State. The way the GeoBolivia project choose to achieve it is making an appropriate technological mitigation between efficiency and simplicity. For example, geographic webservices are still largely unknown to the Bolivian geographers and system engineers but are a necessary element of any SDI. In this case, the solution has been to provide an extensive offer of technical training to upgrade the skills of the State technical manpower. On the other end, some public institutions were installed a cutting-edge SDI framework but never adopted it, leaving the database empty. The solution in this case has been to give them a remote access to their data on the central node of the IDE-EPB, instead of operating

their proper node, that was overkilling their needs and capacity.

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