

LADM Implementation in Colombia

– Process, Methodology and Tools Developed and Applied

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SUMMARY

The Swiss Government currently supports the financing of a project that provides technical assistance to the Colombian institutions for establishing the conceptual and technical bases of a modernized land administration.

Because of the large number of institutions involved in land administration in Colombia, and the need for improved data interoperability, the project Implementing Agency suggested a Model-Driven Approach, where the adoption of the Land Administration Domain Model (LADM) described in the ISO 19152:2012 norm, plays a central role.

Based on Germann et al. (2014), the project then proposed to describe the conceptual LADM country profile of Colombia with INTERLIS, a data model description- and exchange-standard successfully used in the Swiss Cadastre and Spatial Data Infrastructure. The developed INTERLIS based LADM data model is presently being used in the World Bank funded Multipurpose Cadastre pilot projects, executed by the Colombian National Planning Department (DNP).

The article provides an overview of the needs in Colombia for new standards to increase data-interoperability in the Land Administration Domain. The detailed data modelling process, from the conceptual country profile of the LADM to the implementing model based on INTERLIS is then described. Furthermore, some technical details regarding the “INTERLIS for LADM approach” are discussed and the specific tools, existing and developed, used for managing the standards and data are explained. A special focus will be given on the Data Validation Tools and its integration with a web service, for massive testing of cadastral data against the model.

Best practices and the recommendation for considering the applied process, methodologies and tools as a LADM Implementing Toolkit will conclude the article.

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1. INTRODUCTION

The first point of the 2016 signed peace accords between the Colombian Government and the Colombian Revolutionary Armed Forces (FARC) contains the agreement on an integral rural reform, including important aspects of a new Multipurpose Cadastre System. This future Cadastre shall help to characterize the actual situation of land tenure and effectively support the previously initiated processes of land restitution, tenure formalization and land access, with the aim to improve the living conditions of rural population (Acuerdo Final, 2016).

With the law for the National Development Plan (Congreso de la República de Colombia, 2015) and later the Public Policy Document (CONPES) for a new Multipurpose Cadaster (Departamento Nacional de Planeación, 2016) the first definitions and specifications for the future cadastre in Colombia have been made, giving special emphasis on the needs for new standards that shall increase data interoperability, and stipulating the adoption of the ISO 19152:2012 (Land Administration Domain Model – LADM).

Additionally, and following Cadastre 2014 (Kaufmann & Steudler, 1998), two important principles of a modern Land Administration are defined: (i) the principle of *Legal or Institutional Independence* allows the institutions with competences over the administration of certain land objects, to manage their respective information and giving it legal certainty; (ii) the principle of *Freedom of Methods* is closely related with the plans to delegate the operation of the future cadastre to third party operators. Within such a scheme, each operator has the choice to decide on the method of data acquisition and platform of data management that they want to apply, conditioned by the need for compliancy with the product specifications defined by the competent Cadastral Authority (IGAC/SNR, 2016). It is expected that this operational scheme will, besides being more cost effective, also boost the technological innovation in this field.

It is within the above-mentioned context that the Swiss Government, through the State Secretary for Economic Affairs (SECO) decided to support the financing of the project “Modernization of Land Administration in Colombia”. The project provides technical assistance and expertise to the several Colombian institutions, with the overall objective to support establishing the conceptual and technical bases for a modernized land administration.

Because of the variety of institutions involved in land administration, and considering the Legal Independence and Freedom of Methods principles and consequently the needs for improved data

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interoperability, the project – after a comprehensive analysis phase – suggested to deploy a *Modell-Driven Approach* (MDA), with the LADM as the elementary standard.

The LADM proposal was eventually adopted by the Colombian institutions and included in the mentioned CONPES document, as well as in the technical specifications to be applied in the pilot projects for the new Multipurpose Cadastre, excuted by the National Planning Department (DNP) with funding from the World Bank.

2. ADOPTING THE LADM IN COLOMBIA

2.1 The LADM

The Land Administration Domain Model (LADM) adheres to the principles and statements of Cadastre 2014 and since it was declared as an international standard through ISO 19152:2012 (ISO/TC 211, 2012), it has been subject to extensive discussions (Lemmen, Oosterom, & Bennett, 2015). The LADM is a conceptual model that captures the semantics related to land administration, based on a set of agreements about “geometry, temporal aspects, metadata and also observations and measurements from the field” (Lemmen, Oosterom, & Bennett, 2015). It is mostly represented as an UML diagram, depicting the classes of objects, their attributes and the values they can take, their relationships and the constraints that condition them. The main classes of the norm are seperated in three thematic packages as well as one subpackage, and can be illustrated by a scheme of four quadrants, as shown in Figure 1.

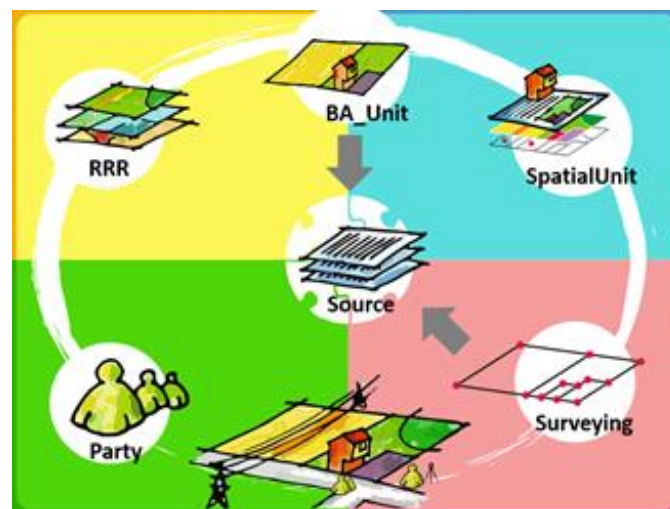


Figure 1: four quadrants (packages) of the conceptual LADM and its main classes
Source: Project “Modernization of Land Administration in Colombia”

2.2 Applied modelling Process and Methodology

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Because of the numerous institutions involved in land administration in Colombia, the process of the conceptual data modelling had to be planned carefully from the beginning. Until now, several workshops were realized in defining a first version of the Colombian LADM profile, together with the specialists of the National Geographic Institute (IGAC), the Property Registry (SNR), the National Land Agency (ANT) and the Land Restitution Unit (URT). Professionals in charge of the National Spatial Data Infrastructure (ICDE in Colombia) and partially of the E-Government Strategy of the Ministry of ICT were involved too, both interested in promoting the inclusion of the LADM-COL profile in their normative frameworks.

Figure 3 explains the four stages of the process, the involved stakeholders and the achieved or planned outputs during each stage.

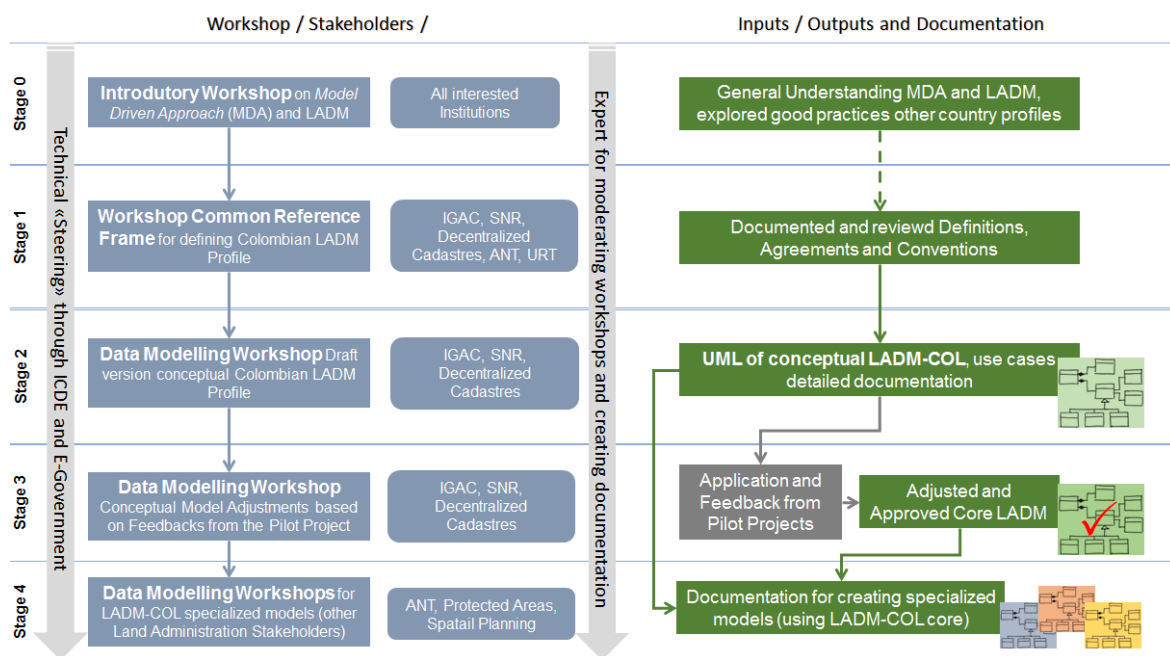


Figure 2: Process and methodology for defining the conceptual Colombian LADM profile
Source: Authors

During stage 0, the model-driven approach was introduced and an elementary course on the LADM was given to all interested institutions. The workshops of stage 1 helped to define *Initial Definitions and Agreements* concerning the modelling approaches for the main classes of the conceptual model (Figure 1). Establishing such a *Common Framework* greatly facilitated the definition of the first draft of the Colombian LADM model (stage 2). The determination of specific naming conventions for classes, attributes and domains later helped to draw a clear distinction between the particular elements of the Colombian LADM profile and the ISO norm.

The actual data modelling workshop of stage 2 started by identifying the objects of the BAUnit class, that is, all the spatial objects that are part of a specific legislation (legal land objects), in

contrast to those that are only a physical description (physical land objects). In a second step, the parties, public or private, natural or legal persons, who are related to the previously identified legal land objects, were determined.

In stage 3 of the process, the data model, applied and verified in the pilot projects of the new Multipurpose Cadastre, will be adjusted. A consolidated version of the LADM-COL core model shall be the result of the 3rd stage. During stage 4, specialized models of the LADM-COL core model are developed together with other relevant land administration stakeholders and with expert advice provided by the project.

2.3 Modular Approach for LADM Implementation - core and specialized Models

Based on the principle of Legal Independence defined for the new Multipurpose Cadastre and considering the Model-Driven Approach, the LADM-COL model is modularized and structured around a *Core or Minimum Model*, containing the common elements that define the profile. The core model is implemented by the institutions that are responsible for each thematic area of data, specializing it according to their missional needs, through specific classes, relationships, attributes, sets of values and constraints (Figure 3).

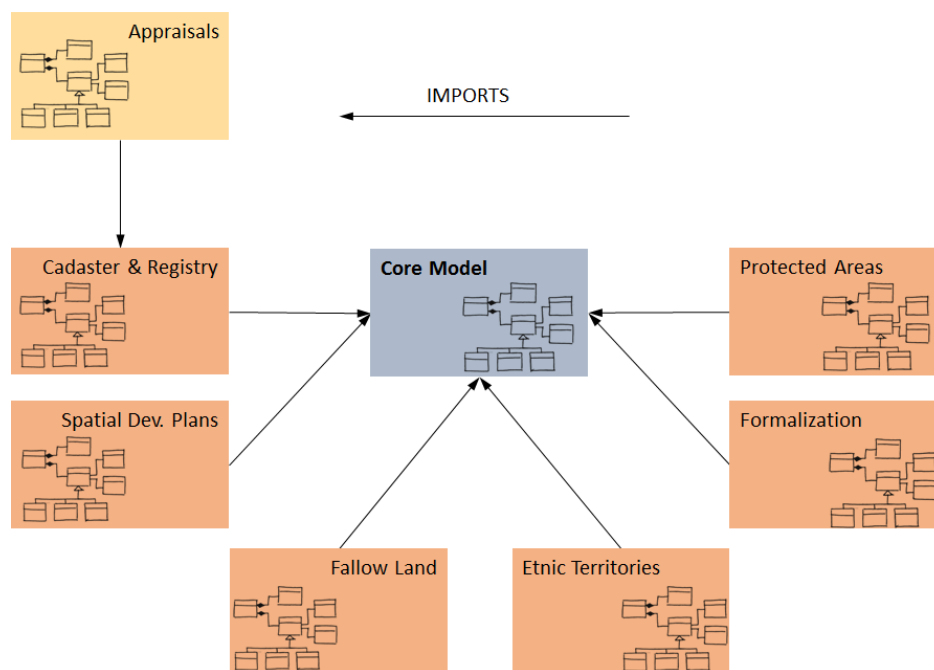


Figure 3: modular approach of the LADM-COL implementation
Source: Project “Modernization of Land Administration in Colombia”

Thus the described *Modular Approach* implies that the Colombian LADM profile will be formed by a core model and its extensions or specialized models for each of the thematic areas, which may represent restrictions or responsibilities in other models, especially in the one for Cadastre &

Registry. In other words, what is represented in a specialized model as a BAUnit according to the legislation of the institution (for example, a protected area is a BAUnit in the Protected Areas model), in another model becomes a restriction (that protected area is a public restriction to full property domain in the Cadastre & Registry model, when its BAUnits – the legal land parcels – are in its area of influence).

3. LADM-COL based on INTERLIS

3.1 Need for System-independent Data-Exchange Mechanism

The new possibility of delegating cadastre works to third parties, including the private sector, implies that solid cadastre product-specifications rather than methods and methodologies must be defined by the Cadastre Authority. With the application of this Freedom of Methods principle any operator should thus be free to decide on the system or platform he wants to use for generating or maintaining cadastral data. This, on the other hand, and if the LADM shall be applied throughout, requires the provision of a model-based and standardized data exchange-mechanism, especially for massive data validation within the scope of quality assurance.

3.2 INTERLIS and LADM as a perfect Match

Regarding the previously described requirement, and based on Germann et al. (Germann, Lemmen, Kaufmann, Oosterromm, & Zeeuw, 2014), the project suggested to implement the LADM based on INTERLIS. The version 2.3 of this Swiss standard is an *object-oriented conceptual schema language*, “which allows to precisely describe data models in a textual form and with a rigid computer-processable syntax” (Germann et al., 2014). Since 2007 INTERLIS has been part of the Swiss Federal Act on Geoinformation (Swiss Government, 2007) and the description of the more than 170 data models of the Swiss National Spatial Data Infrastructure (NSDI) with the standard is stipulated by law.

INTERLIS follows the Model-Driven Approach principles, as it “enables the utilization of data modelling in close connection with a system neutral (XML-based) interface format” (Kalogianni, Dimopoulou, Quak, & Oosterrom, 2016). Thus, by applying INTERLIS to the proposed model, “directly implementable data models are provided, which support the technical implementation of LADM” (Germann et al., 2014).

Another important advantage of the standard, not only in the context of the new Multipurpose Cadastre in Colombia, is the possibility to “quality check INTERLIS data (XML) against INTERLIS data models, thereby enabling fully automated quality control or validation of data” (Germann et al., 2014). This important aspect will be further explored below.

The INTERLIS based LADM-COL model is currently part of a set of product specifications that must be applied by the operators of the World Bank funded pilot projects of DNP.

3.3 Structure of the INTERLIS based LADM-COL

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The current LADM-COL profile consists of the following INTERLIS models (Figure 4):

- the ISO 19107:2003 model, necessary for the definition of used geometries, reference system and coordinate range;
- the ISO 19152:2012 model in its original language (English);
- the ISO 19152:2012 model as a Spanish translation (UNE-EN ISO 19152, 2013), maintaining the reference to the elements of the English version to allow a referential unit to the general syntax;
- the *Core or Minimal Model*, defined by identifying the elements of the LADM-COL profile that are common to the institutional needs;
- the specialized or extended models, by institution or legislation.

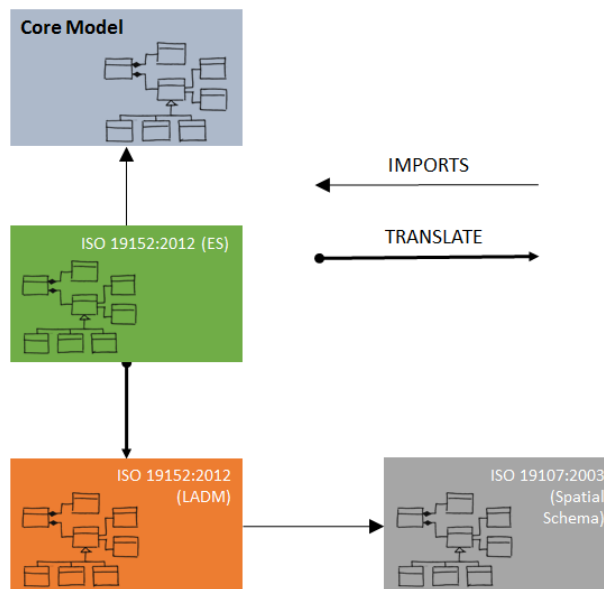


Figure 4: scheme of the modularized LADM-COL model
Source: Project “Modernization of Land Administration in Colombia”

The following detail (Figure 5) of the class “terreno” (lot) of the current version of the model illustrates how the basic class of the ISO norm are extended, as well as how its relation with the specialized BAUnit class “predio” is modelled using INTERLIS.

INTERLIS Model Description

| UML of the involved classes

```

CLASS Terreno EXTENDS LA_BAUnit =
  areaRegistral: MANDATORY 0.0 .. 99999999999999.9 [m2];
  areaCalculada: MANDATORY 0.0 .. 99999999999999.9 [m2];
  ...
END Terreno;

ASSOCIATION PredioTerreno =
  Apredio -<> {1} Predio;
  Aterreno -- {0..*} Terreno;
END PredioTerreno;

```

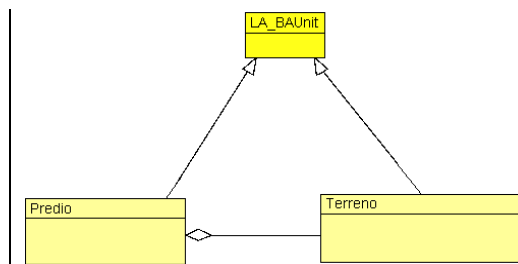


Figure 5: description of the extended BAUnit class "terreno" and its relation to the class "predio"
Source: Authors

4. IMPLEMENTATION THROUGH AN ECOSYSTEM OF TOOLS

To facilitate the implementation of the LADM based on INTERLIS and in compliance with the principles defined for the new Multipurpose Cadastre (Legal Independence, Freedom of Methods), a variety of tools are needed to allow the use of the standard.

In fact, the actual situation in Colombia in some way can be compared to the moment when the Swiss Federal Act on Geoinformation was introduced in 2007 (Swiss Government, 2007), with INTERLIS as the standard for describing all datasets of the Swiss NSDI. At that time, a freely available and complete software ecosystem had to be provided to meet the requirements of the Act. Some of the tools were available, others had to be enhanced or developed from scratch.

4.1 Workflow of an INTERLIS Model Implementation

The tools used for implementing an INTERLIS based model are best described using the example of a typical workflow for such a model implementation:

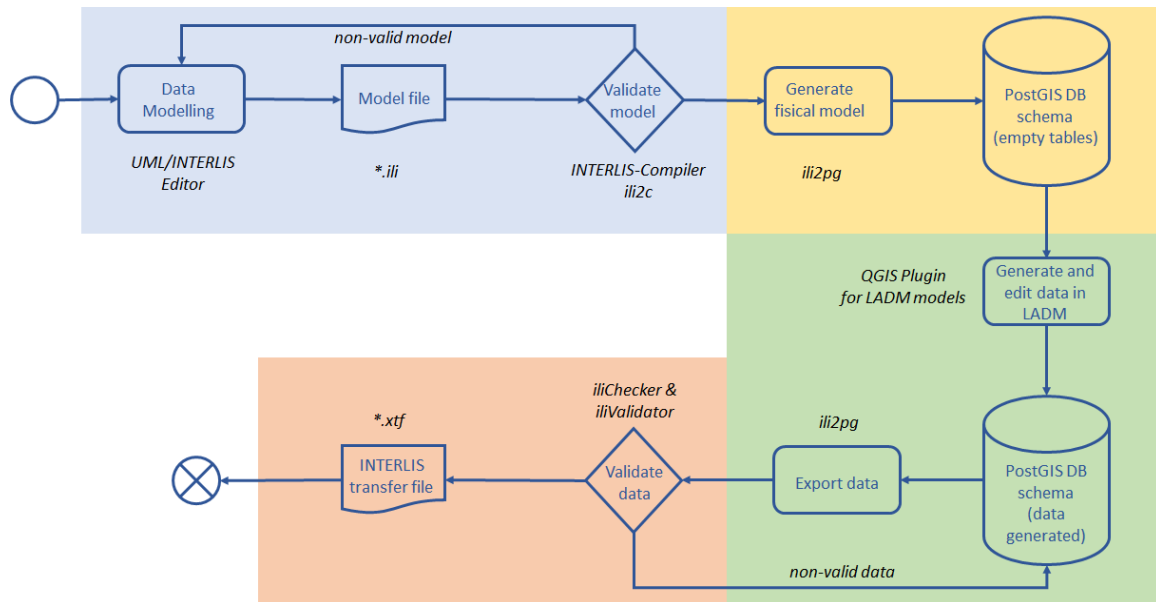


Figure 6: work flow of an INTERLIS model based LADM implementation
 Source: Project “Modernization of Land Administration in Colombia”

- During the data modelling phase (Figure 6, blue), the UML/INTERLIS-Editor can be used for diagramming in UML and then generate automatically the model file (*.ili). The INTERLIS-Compiler tool (ili2c) validates the sytaxis and semantic compliance of the created data model. It can also be used for creating the XML based exchange format (called XTF), besides other outputs (XML schema definition, etc.). Both, the model file *.ili as well as the data file *.xtf can be edited with any freely available ASCII editor (Notepad++, etc.).
- In the phase of creating a platform dependent physical data model (yellow) – the Freedom of Methods/platforms principle applies here – the tools ili2pg or ili2pgpk might be used for translating the objet-oriented INTERLIS model to a relational data base (PostgreSQL/PostGIS or Geopackage).
- In the data aquisition, editing and export phase (green) – also underlying the Freedom of Methods/platform principle, a QGIS plugin provides assistancy in generating model compliant data and once more ili2pg is used for exporting the data to the XML-based INTERLIS exchange format (XTF).
- The data validation phase (red) is again platform independent and either the iG/Check (licensed) or the iliValidator (open source) can be used for validating data against a model. The result is a model conform INTERLIS exchange file in XTF (by the way readable by any GIS that recognizes the GDAL-OGR library for vector formats).

4.2 Description of the used core Tools

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Ili2pg, the tool used for the “generic implementation” (Staub, 2016) of any INTERLIS based LADM in a PostGIS database, the QGIS plugin for detecting the generated database scheme and editing data of the LADM main packages and finally, the INTERLIS data validation tools for testing third-party data against an official data-model are of specific interest and will be described in detail below.

4.2.1 Ili2pg

Ili2pg is a tool that can deal with INTERLIS in several ways¹:

- Translation of INTERLIS data model definitions to a PostgreSQL/PostGIS database.
- Load (import) INTERLIS data into a PostgreSQL/PostGIS database.
- Extract (export) INTERLIS data from a PostgreSQL/PostGIS database.

A big challenge is the break between the object-oriented INTERLIS data model and the used relational database (PostgreSQL/PostGIS, in the case of ili2pg). The translation of the INTERLIS data model to a database is a so-called object-relational mapping (O/R mapping), a common task in data base design. As a user of an O/R mapping software, it is important that this software performs the O/R mapping in a well-documented way. Ili2pg follows some best practices, which are well-known and approved in the IT world. It even supports three different options of O/R mapping. Depending on the data model and the task at hand (data acquisition, transfer of data, etc.), the user has to select the appropriate options.

During the translation into the relational database, all required information from the conceptual INTERLIS data model (e.g. all the classes with all their attributes including structures and domain values) is stored in the database schema in tables. It is thus ensured, that data can be acquired completely according to the defined conceptual INTERLIS data model. It is also guaranteed that the generated data can be exported loss-free into an INTERLIS transfer file (XTF). Besides translating a data model to a database, ili2pg can import and export model compliant data in the XTF format.

There are similar tools that work with common databases like GeoPackage and Oracle, however only ili2gpkg (GeoPackage) has the same set of features like ili2pg at the moment. The program is written in Java and can be executed in the command line or through a simple GUI. As Java library, it can be easily integrated with other Java software.

4.2.2 iG/Check and iliValidator

A major advantage of INTERLIS, as already mentioned, is the possibility to validate the model compliancy of transferred data against its data model (Germann et al., 2014). It is good practice to do so before importing into a database or after exporting to an INTERLIS transfer file. In addition to validate the model compliancy it is important that one can define custom checks. It even has to

¹ <http://www.eisenhutinformatik.ch/interlis/ili2pg/>

be possible to check against other data (which is not part of the transferred data) or to exacerbate the requirements of the INTERLIS data model by defining additional constraints. In other cases, for instance when not all the required data is available, it is necessary to switch off some of the constraints defined in the data model.

To perform the described tasks, two software options exist:

- iG/Check is the official software tool extensively used for the validation of INTERLIS datasets in Switzerland. It supports all major features of the INTERLIS language including constraints. iG/Check is used at the core of the commercial infoGrips Check Service, processing more than 1000 checker jobs per day in average. A free and unlimited standalone version of iG/Check can be downloaded from www.interlis.ch.
- The open source alternative to iG/Check is called iliValidator. Its development started in spring 2016 through co-funding of two cantons of Switzerland and the project in Colombia. Again, Java was chosen as the programming language and the tool can be used with a simple GUI or on the command line. The errors that are detected during validation are logged in an ASCII log file or in an INTERLIS transfer file for visualization purposes. With a configuration file the user can switch on/off the constraints or downgrade them to warnings instead of errors. Using iliValidator as a programming library allows integration of the validation step with existing software, web services and/or existing processes.

4.2.3 QGIS LADM Project Generator

The "LADM Project Generator and Editing plugin" for the open source GIS QGIS, assists during the workflow of generating and editing data according to the LADM model. The plugin allows reading a PostGIS database schema generated from any INTERLIS based LADM model and provides forms and data type widgets required for the correct manipulation of data according to model's classes, attributes, data types, relations and constraints.

4.3 System integration of the Tools and SDI for Land Administration

An important aspect of the described INTERLIS ecosystem is its modularity: every tool does one or a few tasks and they can be easily coupled together, either as a programming library or as simple system calls. All open source tools can be integrated with a hybrid GIS environment (FOSSGIS and proprietary solutions) without violating the open source licenses.

In Colombia, the above described advantages of the tools were used to develop a web based system that helps in receiving and validating cadastre data generated by the contracted surveying companies of the DNP led pilot projects. The system, has been designed in a way that it could easily be used by other land administration institutions.

The reception and validation system consists of several modules, centralized around a web portal, including a dashboard of statistical indicators, a GIS module for visualizing the gathered and

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validated data and for publishing it to different users, a document repository with the aim of managing all documents which are administrative or spatial sources of the LADM-COL.

The core module of the system allows the validation of INTERLIS data through a web interface. It can be used by operators and supervisors of the pilot projects, as well as by other entities that generate data in compliance with the Multipurpose Cadastre data model (or other official models). This implies a very important conceptual and technological advance for Colombia since, with approximately 14 million registered properties in the country, only a web based and therefore automated validation process would allow this volume of information to be treated in an adequate and timely manner. The development of the validation service is done with the Java web framework Spring Boot. The validation logic itself is part of the iliValidator library, all the web service part is done by Spring Boot. The validation service takes advantage of the model repository module. There, all official INTERLIS data models are registered and when proceeding to validate a data set, the corresponding data model can be selected.

The data reception and validation system for the new Multipurpose Cadastre depicts the conceptual and technological basis for the construction of a future SDI for Land Administration within the framework of the National Spatial Data Infrastructure (ICDE). For doing so, the described Model-Driven Approach provides a practicable way for seamless integration and consolidation of all land administration related data, just as in the case of the Swiss NSDI (Staub, 2016). INTERLIS has therefore been considered for the normative framework of the the SDI for Land Administration.

5. GOOD PRACTICES AND CONCLUSION

The best practices described in this article for a feasible implementation of the LADM, can be divided into a methodological procedural part and a more technological part. Regarding the process of modelling a LADM country profile and the design of an appropriate methodology, the following points should be considered:

- In a first step, a general decision for applying the Model-Driven Approach, made by the involved Governmental institutions, should be taken
- In a next step, a consensus on a common set of initial definitions and agreements on the modelling approach, valid for all involved stakeholders, must be defined.
- During the modelling workshops, the protagonists are the thematic specialists of the involved institutions, although guided by experts of the ISO norm.
- It is recommended to proceed individually with each institution, focusing first on Cadastre and Registry, and identifying the semantic elements of the country's context.
- The conceptual model of a LADM country profile is not an objective in itself, but one step in the implementation of the model. Hence, the iterative improvement of the model continues until an acceptable representation of the described reality is achieved. Then it must be moved on to the “level” where the model is described in INTERLIS.

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- Appointing a special modelling workgroup on basis of an interinstitutional agreement helps to streamline efforts and get to a result with less iteration rounds.
- It is needed to develop courses on the ISO19152 and particularly the LADM-COL, directed to all professionals involved in the use of the model.

Regarding the INTERLIS based Model-Driven Approach for implementing the LADM, the following points are considered being important:

- A lesson learnt from Switzerland: although the Act on Geoinformation is a milestone in terms of applying the Model-Driven Approach for the NSDI, the law itself was not enough to achieve the breakthrough of the modeling language INTERLIS: An ecosystem of tools, which fulfills all requested tasks of implementing the model-driven approach, is needed.
- These tools are now available, both, as FOSS and as licensed solutions. Since they are totally based on the Model-Driven Approach, they can be deployed and further enhanced if required, for any actual implementation of the LADM in any context of country.
- Introducing INTERLIS for implementing the LADM, must be accompanied by specific training courses, in the standard as well as in the application of the developed tools. Creating awareness concerning the importance of the Model-Driven Approach on a decision-taking level also is crucial for a practicable implementation of the LADM based on INTERLIS.

The successful application of the modelling process, methodology, and INTERLIS base models and tools in Colombia, can be considered as an *LADM Implementing Toolkit*, offered to be used by countries that face similar challenges as Colombia in modernizing their land administration.

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BIOGRAPHICAL NOTES

Lorenz Jenni studied surveying and geomatics at the University of Applied Sciences in Basel and has a master's degree in GIS of the Universitat Politècnica de Catalunya. The last 15 years he has been working as a consultant in cooperation projects related to land administration and land information management, with Swiss Government, KfW, European Union, IDB and the World Bank, in Latin America, Caribbean and South East Europe. Currently he is the technical team leader of the project “Modernization of Land Administration in Colombia”.

Michael Germann is co-founder and CEO of infoGrips LTD, Zürich Switzerland and member of the Swiss Land Management Foundation (SLM). In 1988, he received a master's degree in computer science from ETH Zürich. His main interests are software development, data modelling, data quality control and the implementation of spatial data infrastructures. He worked on several Swiss standards including INTERLIS and was part-time member of the Swiss delegation to ISO TC211.

Claude Eisenhut holds a degree in technical computer science from Bern University of Applied Sciences, Engineering and Information Technology, Switzerland. From 1991 until 1997 he worked for a Swiss GIS vendor as a software developer. Since then he works as an independent consultant and is the CEO of Eisenhut Informatik AG, a company that develops tools for implementing the INTERLIS standard. Part of his work included the development of the data model for the legal part of land administration in Switzerland (eGRISDM). He has been member of the commission for discussing and approving the LADM as an ISO norm.

Andrés P. Guarín López is a cadastral engineer and geodesist, with a master in information sciences and communications from the Universidad Distrital Francisco Jose de Caldas. During his professional occupation, he has been the technical leader for implementing several GIS projects, from analysis, design, and development to the implementation stage. He was engaged in drafting the conceptual design of the new Multipurpose Cadastre of Colombia and is currently working for the National Land Agency as a consultant for the institution's Land Information Management.

Víctor M. Bajo Perez holds a degree in forestry engineering of the Universidad Politécnica de Madrid and a master's degree in natural risk management of the Universidad de León. Currently he is completing an applied master in multipurpose cadastre at the Universidad de Jaén. His professional dedication in recent years has focused on GIS applications for Land Management and its use at a local government level, aimed to implement decentralization policies. Víctor works as a freelance consultant for international development cooperation projects, with IDB, EU, KfW, Development Bank of Latin America and currently SECO in Colombia.

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