



**DEVELOPMENT AND EMPLOYMENT OF AN LADM IMPLEMENTING TOOLKIT
IN COLOMBIA**

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**Paper prepared for presentation at the
“2017 WORLD BANK CONFERENCE ON LAND AND POVERTY”
The World Bank - Washington DC, March 20-24, 2017**

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Responsible Land Governance: Towards an Evidence Based Approach

ANNUAL WORLD BANK CONFERENCE ON LAND AND POVERTY
WASHINGTON DC, MARCH 20-24, 2017



Abstract

The Swiss Government is currently financing a project which provides technical assistance to the Colombian institutions in order to establish the conceptual and technical bases of a modernized land administration.

This paper explains the data modelling process and methodology applied by the project for adopting the ISO19152 (Land Administration Domain Model) in Colombia and for describing the LADM country profile using the *Conceptual Schema Language INTERLIS*, as well as the development of specific Free and Open Source Software tools that support the countrywide implementation of the standard.

The project's *Model-Driven Approach* responds to the conceptual framework of the Multipurpose Cadastre defined by the Colombian Government, where the operation of the cadastre will be delegated to third-party operators by applying a "Freedom of Methods" principle. Because of this principle, a system independent data exchange mechanism is needed, a requirement that INTERLIS meets. With the developed *Data Validation Tool* and its integration with a web service, data delivered by the cadastre operators is checked against the LADM-COL model.

With the defined, well-documented and successfully applied modelling process, methodology and deployed tools, a *LADM Implementing Toolkit* is at the disposal of countries that face similar challenges as Colombia in modernizing their land administration.

Key Words:

Automated Data Validation, FOSS, LADM based on INTERLIS, Model-Driven Approach, Multipurpose Cadastre Colombia

1. Introduction

1.1. Post-Conflict, Peace-Accords and Land Issues in Colombia

The recently signed peace accords between the Colombian Government and the Colombian Revolutionary Armed Forces (FARC) shall bring an end to a conflict that has lasted 50 years leaving more than 220,000 dead, 25 thousand missing, 4.7 million displaced persons and thousands of children recruited, among other victims (Grupo de Memoria Historica, 2013). Regarding one of the main causes for the conflict the Land GINI Coefficient close to 1¹ shows that the problem of land concentration must be addressed together with land access and land tenure security as basic issues to improve rural population opportunities to overcome historical poverty (Departamento Nacional de Planeación, 2015).

Because of the weakness of the current country's cadastral and registry information systems it is not possible to have an exact figure on the hectares of land abandoned or dispossessed, but an approximated figure is that about 6.5 million hectares have been affected by displacement processes (González, 2013).

On this account, point one of the peace accords contains the agreement on an Integral Rural Reform, including important aspects on how to create and maintain an Integrated Multipurpose Cadastre System, understood as a means to accurately characterize the actual situation of land tenure in the country (Acuerdo Final, 2016), so that the initiated processes of land restitution, tenure formalization and victim reparation can be carried out effectively and in a sustainable manner.

1.2. New Multipurpose Cadastre – Needs for new Standards of Data Interoperability

The existing Colombian cadastre has a centralized organizational structure where the National Geographic Institute Agustín Codazzi (IGAC) regulates and operates the cadastre in a large number of municipalities. Additionally 4 decentralized cadastre authorities exist, with the responsibility of cadastre maintenance in certain municipalities and metropolitan districts. And finally, many public and private agencies are involved in property management and parcel surveying around the country. This scheme has showed to be insufficiently effective in guaranteeing total coverage of the country with accurate and, above all, updated cadastre information.

Hence, in the Law 1753 of 2015 for the National Development Plan (Congreso de la República de Colombia, 2015) the Colombian Government defined the strategic vision of a multipurpose cadastre that allows and guarantees the interinstitutional exchange of information on land and its structural elements, with the registration of private and public property records, as a basis for an effective administration of all land objects of the country.

¹ “Land Gini Coefficients between 0.8 - 0.9” (Departamento Nacional de Planeación, 2015)

This strategic vision begins to materialize with a Public Policy Document (CONPES) for a new Multipurpose Cadastre (Departamento Nacional de Planeación, 2016), where the current outdated state of the cadastre in the country² and the negative implications of having such an outdated cadastre are made. The document further proposes mechanisms and tools for the improvement of the cadastre system and the standardization of its information, adopting a Colombian profile of the LADM, ISO 19152:2012. Likewise, the CONPES defines the construction of a National Land Management System, which, based on Interoperability and the principle of *Legal Independence*, allows the institutions with competences over the administration of certain spatial objects, to manage their respective information and giving it legal certainty. Cadastral-registry information will be at the heart of this future National Land Management System (UNHCR ACNUR, 2012).

1.3. Freedom of Methods – a basic Principle of the New Multipurpose Cadastre

A principle of elementary importance of the new Multipurpose Cadastre is the *Freedom of Methods* (IGAC/SNR, 2016). This is especially relevant when taking into account the idea of a future delegation of the cadastre operation to a local territorial level and even the private sector, breaking the current centralized operational scheme.

The principle of Freedom of Methods says that each operator is responsible for their own methods of data acquisition and management, always guaranteeing the compliance of the product specifications defined by the competent Cadastral Authority (IGAC/SNR, 2016). It is expected that this new operational scheme will, besides being more cost effective, also boost the technological innovation in this field.

Consequently, the principle of Freedom of Methods also applies to the data management and information systems used during both, the first surveys as well as the cadastre maintenance process, making necessary a mechanism that allows a platform neutral implementation of the LADM in Colombia, as well as tools for the validation, integration and consolidation of the data.

1.4. Swiss Cooperation Project “Modernization of Land Administration in Colombia”

Within the above mentioned context, the Swiss Government, through the State Secretary for Economic Affairs (SECO) decided to support the financing of a project that provides technical assistance and expertise to the Colombian institutions, with the overall objective to establish the conceptual and technical bases for a modernized land administration.

² About 28% of the territory has no cadastral coverage and 63.9% of the territory only outdated information (Departamento Nacional de Planeación, 2016), being the areas affected by the armed conflict the ones with the highest levels of outdatedness.

The “Modernization of Land Administration in Colombia” Project, executed by an Implementing Agency, and structured in close collaboration with Colombian institutions, with competences in land administration, includes six thematic working areas, all of them closely linked with aforementioned Government strategies.

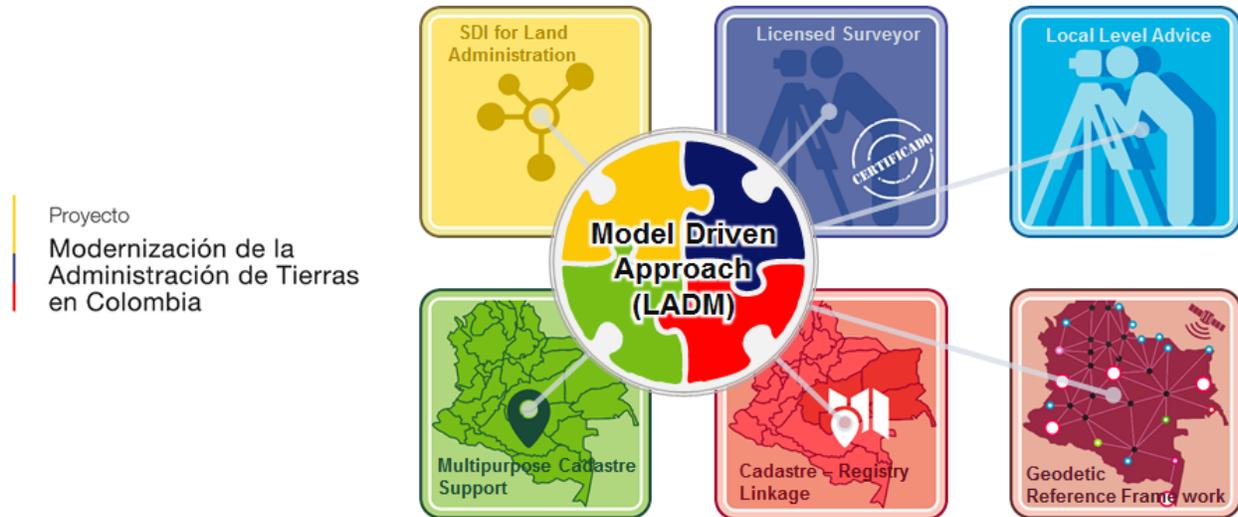


Figure 1: Thematic areas of the project.

Source: Project “Modernization of Land Administration in Colombia”

The thematic working areas include (Figure 1): i) contribution to the construction of a Spatial Data Infrastructure for Land Administration (SDI-LA) within the framework of the Colombian Spatial Data Infrastructure (ICDE), ii) provision of technical assistance in developing the vision of the Licensed Surveyor’s role for the future management of the Multipurpose Cadastre and Land Administration, iii) support the pilot projects led by the National Planning Department (DNP), with emphasis in giving technical advice to the Cadastral Authority, iv) strengthen land administration at local entity level, in the framework of the new Multipurpose Cadastre, v) giving technical advice in improving interoperability between Cadastre and Property Registry, vi) provision of technical assistance in enhancing the Geodetic Reference Framework for efficient Land Administration.

Because of the complex institutional setting for land administration in Colombia, and consequently the need for legal independence and improved data interoperability, the project – based on a comprehensive analysis phase – suggested a *Modell-Driven Approach* (MDA), with the LADM as the elementary standard.

All leading land related institutions eventually accepted the LADM proposal made by the project, by considering the norm in the already mentioned CONPES document (Departamento Nacional de Planeación, 2016), and successively a first draft version of the Colombian profile of the ISO norm was

developed. This draft version is being applied and verified in the World Bank funded Multipurpose Cadastre pilot projects executed by DNP and will be subsequently brought to further perfection.

2. LADM Country Profile of Colombia

2.1 The Land Administration Domain Model

The Land Administration Domain Model (LADM) is the result of different ideas embodied in Cadastre 2014 and subject to extensive discussions (Lemmen, Oosterom, & Bennett, 2015), especially since it was concretized as an international standard through ISO 19152:2012 (ISO/TC 211 Geographic information, 2012). The LADM is a conceptual model that captures the semantics related to land administration, based on agreements about “geometry, temporal aspects, metadata and also observations and measurements from the field” (Lemmen, Oosterom, & Bennett, 2015). The data model, mostly represented as an UML diagram, depicts the classes of objects, their attributes and the set of values they can take, their relationships and the constraints that condition them, within the framework of the description of the reality of land administration.

2.2 Conceptual Modelling Process and applied Methodology

The conceptual modelling process and methodology for defining a Colombian LADM Profile was planned in detail and systematically documented from the beginning.

Starting in September 2015, so far it has taken place during several workshops, with the technical assistance of experts in the norm who moderated the modelling sessions with the specialists of the involved institutions such as IGAC, Decentralized Cadasters, Property Registry (SNR), National Land Agency (ANT, former INCODER), Land Restitution Unit (URT), among others.

An import external “steering” stakeholder in the modelling process was the ICDE as well as the Ministry of ICT, both interested in promoting the inclusion of the defined country profile in their normative framework of ICDE respectively national E-Government Strategy.

Figure 2 provides an overview of the still ongoing process, with expected adjustments to the model after finalizing the Multipurpose Cadastre pilots of DNP (stage 3) and the successive definition of specialized models particularly for public law restrictions and responsibilities.

Despite the in-advance defined process and planning of stages, not all activities could be streamlined and many inputs were delivered little by little, as for example in the case of the Cadastre Object Catalogue or the provision of the definitive lists of domain values. This resulted in the draft model having to be adjusted during several additional working meetings, including updating the respective documentation.

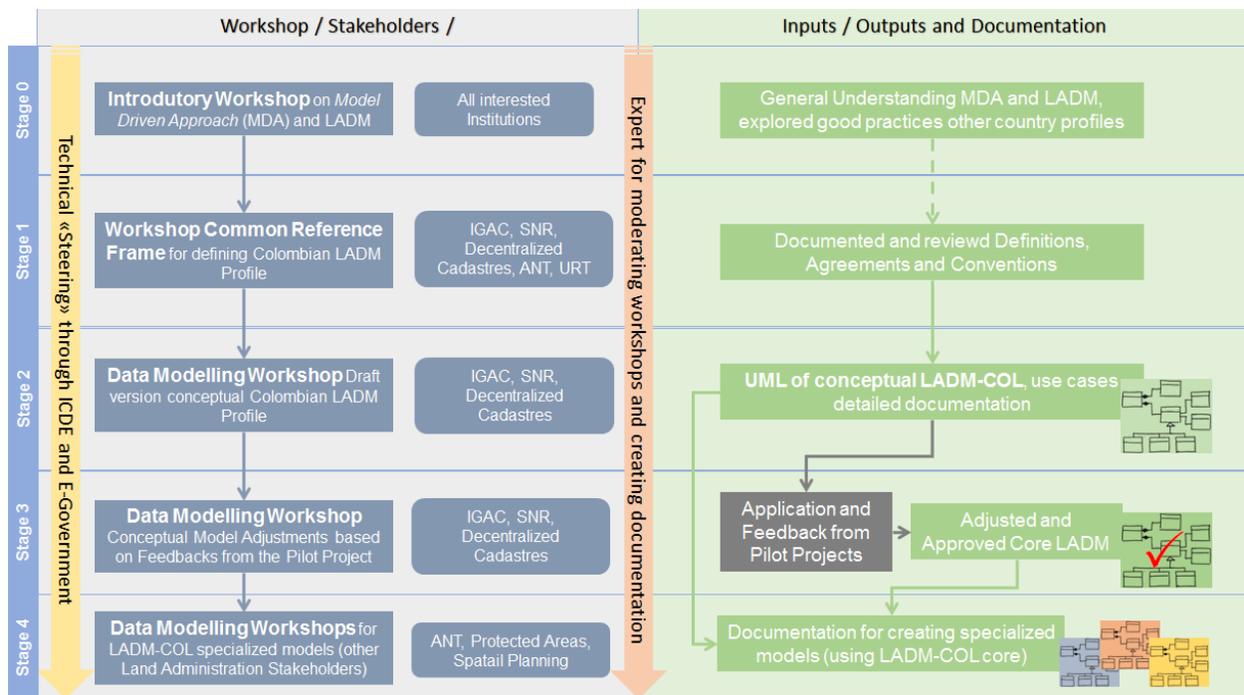


Figure 2: Process and Methodology for defining the conceptual Colombian LADM Profile.

Source: Authors

During the workshop of stage 1 of the process, *Initial General Definitions and Agreements* concerning the modelling approaches for the main classes BAUnit and SpatialUnit, Rights, Restrictions and Responsibilities as well as for the handling of the Geometries (Surveying and Representation Sub-package) were defined. This was done in consensus between the thematic specialists of the participating institutions. With this a *Common Framework* for the definition of the first draft of the conceptual model in stage 2 could be established. The determination of specific naming conventions for classes, attributes and domains helped to draw a clear distinction between the particular elements of the Colombian LADM profile and the ISO norm.

During the following data modelling workshop (stage 2), the first draft version of the conceptual LADM model for Colombia was defined. A good starting point for this was to identify in a first step the objects of the BAUnit class, that is, all the spatial objects that are part of a specific legislation (legal spatial objects), in contrast to those that are only a physical description (physical spatial objects). In a second step, the parties or stakeholders, public or private, natural or legal persons, who are related to the previously identified legal spatial objects, were specified.

Implementation of stage 4 is already ongoing, as it will be explained in further detail below.

2.3 Main Features of the Conceptual Country Profile LADM-COL

The first version of the conceptual country profiles LADM-COL, described in UML, included the following main features in comparison to the ISO norm (Figure 3):

- Variety of specialized classes of LA_BAUnit (applied “BAUnit approach modelling” (Proyecto Modernización de la Administración de Tierras de Colombia, 2016).

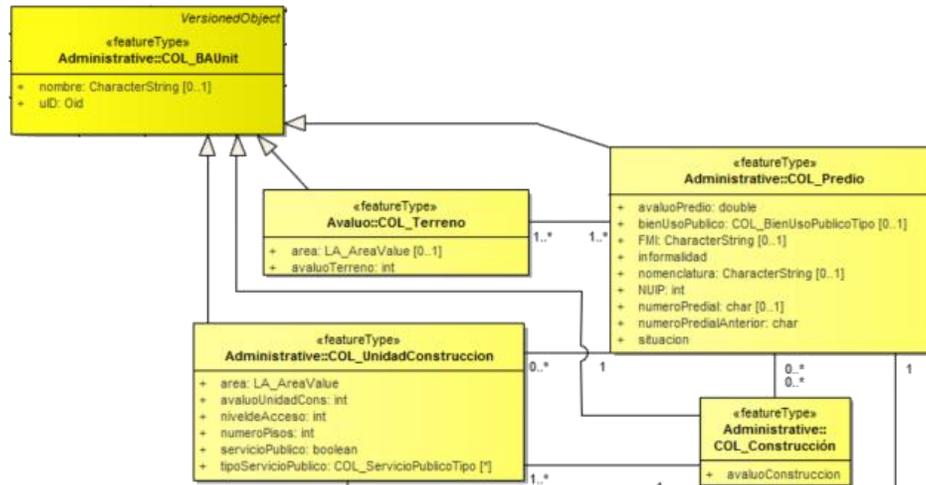


Figure 3: Process and Methodology for defining the conceptual Colombian LADM Profile.

Source: Project “Modernization of Land Administration in Colombia”

- COL_Predio (legal parcel) and COL_Terreno (lot), whose existence is interdependent, means they must co-exist, because the cadastral regulation indicates that a parcel exists on an existing lot.
- COL_Construccion, a class where instances must not exist if there is not a COL_UnidadConstruccion (Construction Unit), which in turn can only exist depending on a COL_Construccion class. Both classes however, are specialized classes of LA_BAUnit.
- COL_BAUnit is the generalized class of the basic administrative units of the LADM-COL cadastre model. Some of its attributes were modified for the Colombian profile.
- The class COL_Alerta is meant to manage alerts concerning requests for Land Formalization or Restitution processes, on a COL_BAUnit. COL_Alerta is a class outside of LADM, created according to the specific needs of the Colombian legislation.
- Utilization of a polygon geometry type in the specialized BAUnit classes with 1:1 relationship with SpatialUnit; the aim is to support management of polygon geometries (the usual case in Colombia), avoiding executing methods to generate polygons in the COL_SpatialUnit class.

GM_Multicurve of the LA_BoundaryFaceString class and GM_Point of the COL_Point class are still maintained as additional options for geometrical representation of the BAUnit classes.

- Class COL_ZonaAfectacion which indicates the extension of the core model with specialized models for restrictions and responsibilities who share other classes of the core model.
- Creation of several new domains and adaption of existing ones, for the specific context of Land Administration in Colombia.
- Including specific new attributes of the LA_Point class used for quality assurance of field measurements.

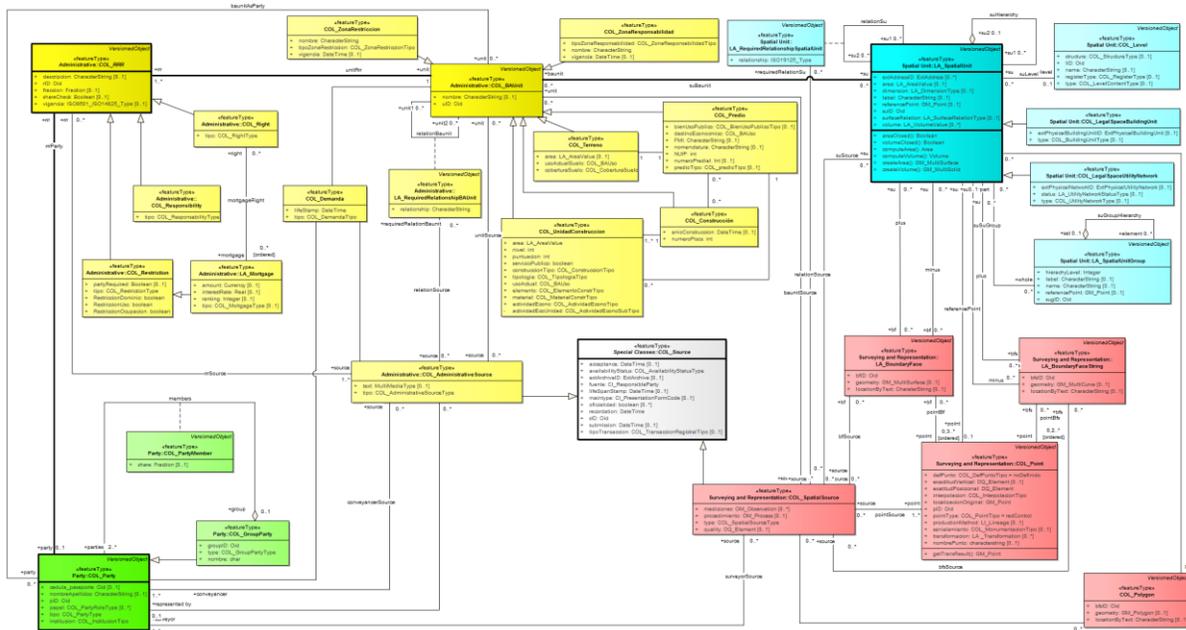


Figure 4: UML of the first version of theLADM-COL Profile.
Source: Project “Modernization of Land Administration in Colombia”

2.4 Applying LADM to other Institutions dealing with Land Administration

The amount of institutions involved in land administration in Colombia, each with its legal regulations and competences related to specific policies and missional processes, will require a carefully structured implementation of the LADM. For this, the consideration of the principle of *Legal or Institutional Independence* (Kaufmann & Steudler, 1998) and concept of an SDI are crucial elements, since in this way, each institution is responsible for the generation and maintenance of its specific data, as well as for its documentation and publication within the national ICDE framework (the National SDI in Colombia).

In this setting, the LADM-COL model is modularized and structured around a *Core or Minimum Model*, containing the common elements that define the profile. The 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 constrictions. This structure, represented in Figure 4, clearly supports the principle of Legal Independence.

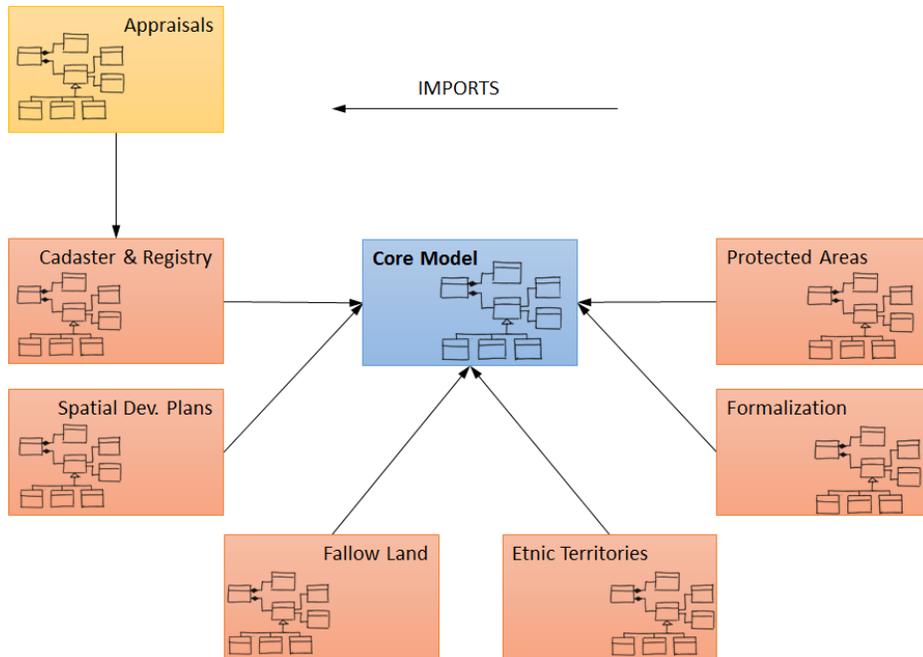


Figure 4: Modularization of the LADM-COL.
Source: Project “Modernization of Land Administration in Colombia”

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 Cadastre and Registry model. Thus, what is represented in a specialized model as a “Basic Administrative Unit” according to the sectoral law of the institution (for example, a protected area will be 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 model, when its BAUnits – the legal land parcels – are in its area of influence). Similar situations occur in the case of Indigenous Reserves or Afro-descendant Communal Territories, as an example.

In this way, a circle of reuse of information that configures the essence of the concept of the Multipurpose Cadastre is established. With data of known and documented quality, the Cadastre is the basis for the creation and improvement of thematic data of other institutions, which, in turn, provide information to the Cadastre.

Within the above concept it is relevant to mention that the project has already started to draft a methodology for defining the LADM-COL specialized models. The methodology will be progressively improved and documented during the workshops (stage 4 of Figure 2) where it is applied for constructing the specialized models of all main land administration stakeholders.

3. LADM-COL based on INTERLIS

3.1 Need for a Platform independent Data Exchange

An essential element of the conceptualization of the new Multipurpose Cadastre in Colombia, is the already mentioned delegation of parts of the cadastre works to third parties (private sector), which implies that cadastre product specifications rather than methods, must be defined. This already described *Freedom of Methods* principle in a consequent manner also connotes that any cadastre operator should be free to decide on the platform he wants to use for producing cadastral data according to the official specifications. This, on the other hand – and if the model driven paradigm shall be observed – obliges the Land Administration Authorities to define a model-based and standardized data exchange mechanism as well as the provision of an ecosystem of tools and platforms which allow automated data validation, and its integration and consolidation in a Land Administration System respectively SDI.

3.2 INTERLIS and LADM as a perfect Match

Regarding this, and based on Germann et al. (Germann, Lemmen, Kaufmann, Oosterom, & Zeeuw, 2014), the project further suggested to implement the developed LADM country profile using INTERLIS, a data model description and exchange standard successfully applied in the Swiss Cadastre System for several decades.

The version 2.3 of INTERLIS applied in Colombia 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, Lemmen, Kaufmann, Oosterom, & Zeeuw, 2014). Although INTERLIS was originally developed for Land Information Systems – as its name suggests – it is not restricted to geographic data modelling and can be considered as a general purpose modelling language. Since 2007 it has been part of the Swiss Federal Act on Geoinformation (Swiss Government, 2007) and the more than 170 data models of the Swiss NSDI have had to be described with the standard by law.

INTERLIS clearly follows the MDA principles, as it “enables the utilization of data modelling in close connection with a system neutral (XML-based) interface format” (Kalogianni, Dimopoulou, Quak, & Oosterom, 2016). Thus, by applying INTERLIS to the proposed model, “directly implementable data

models are provided, which support the technical implementation of LADM” (Germann, Lemmen, Kaufmann, Oosteromm, & Zeeuw, 2014).

Another important aspect of the standard is that it is possible to quality check INTERLIS data against INTERLIS data models, thereby enabling fully automated quality control of data. This important aspect with regard to the context of the new Multipurpose Cadastre in Colombia will be further explored below.

All these advantages were carefully weighted and the *LADM based on INTERLIS approach* has been adopted so far by the Colombian institutions and the INTERLIS LADM-COL model is now part of a set of product specifications that have to be applied during the World Bank funded pilot projects.

3.3 Process of Describing the conceptual LADM with INTERLIS

The description of the Colombian LADM profile through INTERLIS, begins when the description of reality in the conceptual model using UML reaches an adequate level of maturity. It is an iterative process that requires a training phase with the involved institutional specialists concerning the general concepts of the INTERLIS language.

The training phase was followed by an inter-institutional workshop where the conceptual LADM-COL profile was described in INTERLIS³. This version received later adjustments, based on the advances in the definition of the technical product specifications of the Multipurpose Cadastre, including the Cadastre Object Catalogue and the Parcel Field Form.

Once the LADM-COL model with INTERLIS as the underlying standard is part of the final technical specifications of the Colombian Multipurpose Cadastre, further actions to include it as an official standard of the national *E-Government Strategy* and the ICDE will be undertaken.

3.4 Structure of the INTERLIS based LADM-COL Model

The current LADM-COL profile consists of the following INTERLIS models (Figure 5):

- the ISO 19107:2003 model, necessary for the description of geometries and the definition of reference system and coordinate range;
- the ISO 19152:2012 model in its original language (English);

³ The Swiss Land Management foundation (SLM) started to describe the LADM with INTERLIS in 2014 (Germann, Lemmen, Kaufmann, Oosteromm, & Zeeuw, 2014). Technical discussions between the project in Colombia and SLM during 2016 led to an improved and leaner version of the LADM base models, used for the construction of any country specific profile (Figure 5).

- the ISO 19152:2012 model as a Spanish translation⁴, 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 national LADM-COL profile that are common to the institutional needs;
- Completing it with the specialized or extended models, by institution or legislation.

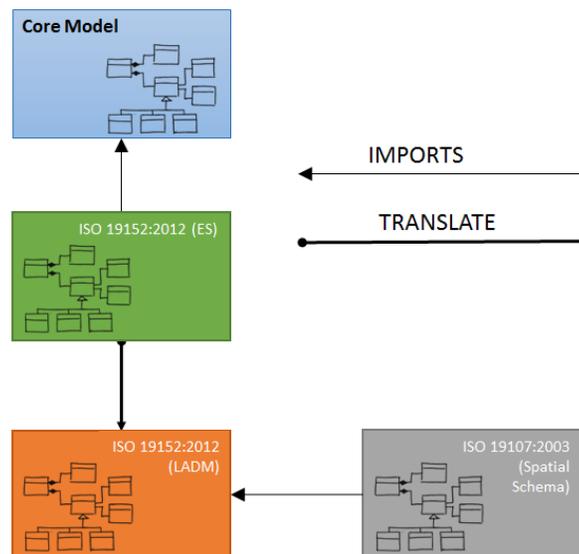


Figure 5: Modularization of the current LADM-COL.
Source: Project "Modernization of Land Administration in Colombia"

4. Development and Deployment of Implementing Tools

4.1 Need for Tools that Support LADM Implementation

To implement the LADM model based on INTERLIS and in compliance with the conceptualization of the Multipurpose Cadastre in Colombia (Legal Independence, Freedom of Methods), it is necessary to develop and enhance existing tools that allow the use of the standard. For this, the use of Free and Open Source Software (FOSS) license-type is considered as the preferred option, as it contributes to platform independence by involving producers of cadastral GIS solutions in the development of an “ecosystem” of tools around the INTERLIS based LADM-COL, beside the benefits of avoiding on-going license costs and hence improve financial sustainability (Stuedler, Törhönen, & Pieper, 2010). Notwithstanding, the by the project preferred use of FOSS does not leave out proprietary licenses; thus, ESRI Colombia, as the major producer of GIS solutions in Colombia, is also being involved in data production based on the INTERLIS exchange format and by employing the tools of the integrated ArcGIS solution. Experiences

⁴ The project suggested to use the official translation of the Spanish Normalization Agency AENOR (UNE-EN ISO 19152, 2013) for this Spanish version of the LADM base model in INTERLIS.

of ESRI Switzerland in applying the standard help their Colombian partners in developing the required applications.

In the software developments of the project itself, Swiss and Colombian experts collaborate, both at the level of users and development specialists, allowing for a transfer of knowledge and an exchange of experiences and points of view.

4.2 The INTERLIS Tools Ecosystem and typical Workflow

INTERLIS is, as described before, a good concept with the appropriate ideas. But every good concept without a sound ecosystem is not practical and will not be accepted by the users. INTERLIS was developed in 1991 and the very first widespread implementation was the adoption of the Official Cadastral Surveying (AV93) in the early nineties in Switzerland. Instead of collecting and managing “dumb” digital data, the Model-Driven Approach (MDA) was chosen. For quite some time INTERLIS was only used in the context of cadastral surveying and therefore for most people in the remaining geo-information sector it was barely known and used.

Everything changed with the introduction of the Federal Act on Geoinformation in 2007 (Swiss Government, 2007), where the MDA for approx. 170 datasets is stipulated. A freely available and complete software ecosystem had to be provided to meet the high standards of the Act. Some of the tools were already available but others had to be enhanced or developed from scratch.

A typical implementation of any INTERLIS data model is done in several steps, using the following tools:

- Data modeling: For the modeling of the INTERLIS data model, one can use UML/INTERLIS-Editor⁵. The INTERLIS data model file (*.ili) can be directly generated from UML/INTERLIS-Editor. Since it is an ASCII file, it can be read and modified in any ASCII editor. For a visual pleasant reading, jEdit or Notepad++ can be used, both editors support syntax highlighting. Already existing INTERLIS data models can be easily imported into the UML/INTERLIS-Editor for documentation of modification purposes.
- Model validation: The syntax and semantics compliance of a newly created INTERLIS data model must be validated. This can be done with the INTERLIS compiler (ili2c)⁵.

⁵ <http://www.umleditor.org>

- Translation of the data model to a database: For data acquisition or provision of the data the object-oriented INTERLIS data model has to be translated to a relational database. With ili2pg (PostgreSQL/PostGIS) or ili2pgk (Geopackage), there is a more than capable tool to do this step⁶.
- Data validation: The data, which is acquired externally, must be validated from the very beginning to gain a high quality. With iliValidator⁷ one can validate the data against its conceptual INTERLIS data model.
- Data import/-export: Besides translating the INTERLIS data model to a database, ili2pg can also be used to import/export data into/from the previously created database tables.
- Data acquisition: With the QGIS LADM Project Generator and Editing plugin, any LADM model PostgreSQL/PostGIS schema can be read and all appropriate data type widgets and relations in the QGIS forms are created automatically.

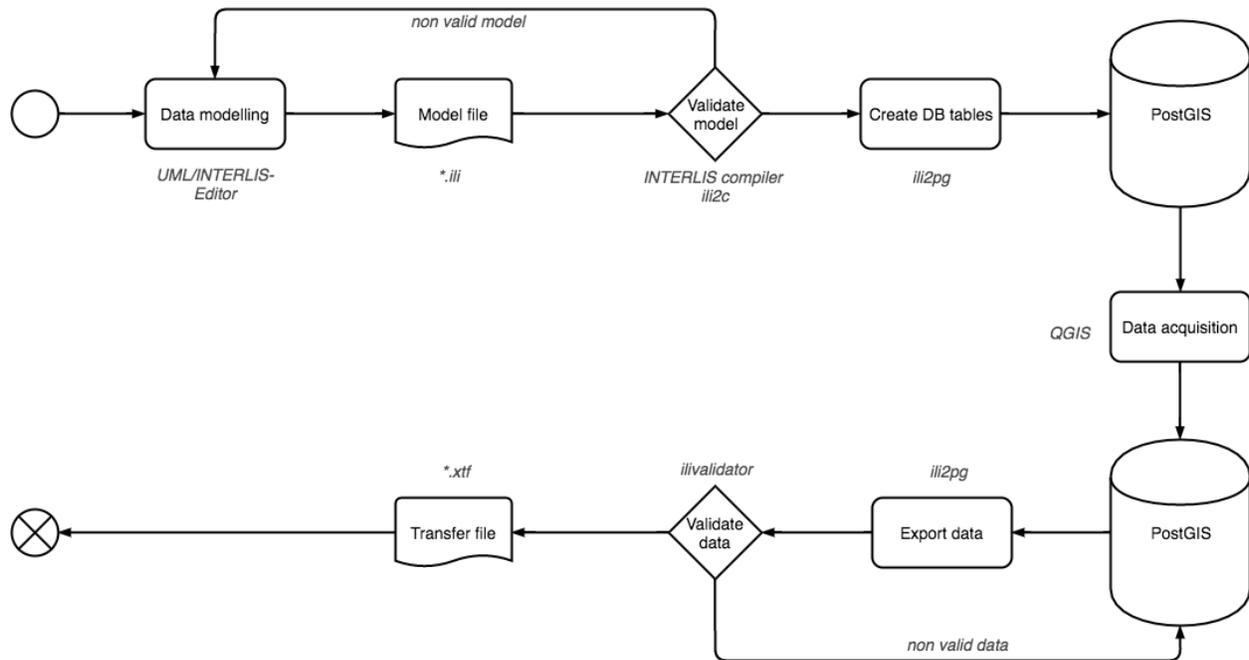


Figure 6: Typical Workflow of an LADM Implementation based on INTERLIS Tools. Source: Authors

In the following, the specific functionalities of each tool of Figure 6 are explained in more details.

⁶ <http://www.eisenhutinformatik.ch/interlis/ili2pg/>

⁷ <https://github.com/claeis/ilivalidator>

4.2.1 UML/INTERLIS-Editor, jEdit and Notepad++

The data modeling process can be done graphically by means of UML diagrams with the UML/INTERLIS-Editor. It is not necessary to know the whole INTERLIS syntax thoroughly, the graphical representation of the INTERLIS data model with UML diagrams helps for a better understanding of all the questions that have to be answered during the modeling process. Existing INTERLIS data models (like an existing LADM country profile) can be imported and be represented with UML diagrams (e.g. for documentary purposes).

The result of an export from the UML/INTERLIS-Editor is the conceptual INTERLIS data model file (*.ili). Since it is an ASCII file, it can be opened in any ASCII editor. Thanks to some plugins, there are at least two editors that support syntax highlighting (jEdit and Notepad++).

4.2.2 INTERLIS-Compiler

The INTERLIS compiler ili2c validates the syntax and semantic compliance of the data model. It also can generate some other useful derivatives:

- The XML schema of the INTERLIS data model (the exchange format)
- HTML tables with all the model's classes and attributes

The INTERLIS compiler is built-in in the UML/INTERLIS-Editor. Hence the user needn't export the model to validate it.

4.2.3 ili2pg

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

- 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.

The biggest challenge is the break between the object-oriented INTERLIS data model and the relational database (PostgreSQL in this case). The translation of the INTERLIS data model to a database is a so-called object-relational mapping (O/R mapping), which is quite common in the field of IT. Lack of understanding of O/R mapping, unnecessary complicated and complex data models and missing tools were some of the reasons that INTERLIS did not get the attention it deserves. These findings and experiences are taken in account when implementing LADM based on INTERLIS in Colombia.

There are no rules by law for O/R mapping and they are not necessary anyway. As a user of an O/R mapping software (like ili2pg is), it is important that this software does 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. Which of these options is the appropriate, depends on the data model and the task at hand. (e.g data acquisition, transfer of data, etc.) and should not be prescribed by some party.

The final result of the translation of the INTERLIS data model into the relational database are empty tables in a database schema. All required information from the conceptual INTERLIS data model (e.g. all the classes with all attributes incl. structures and enumerations) is stored in the database schema in tables. It is thus ensured, that data can be acquired completely according to the INTERLIS data model and also can be exported loss-free into an INTERLIS transfer file.

Besides translating an INTERLIS data model to a database, ili2pg can load (import) model compliant data to the database and extract (export) the data from the database.

Ili2pg is part of a whole family of similar tools that work with other databases like GeoPackage and Oracle, however only ili2gpkg has the same set of features like ili2pg at the moment. It is written in Java and can be executed in the command line or through a simply GUI. As Java library, it can be easily integrated with other Java software.

4.2.4 iliValidator

A big advantage of INTERLIS is the possibility to validate the model compliancy of the transferred data against its data model (Germann, Lemmen, Kaufmann, Oosteromm, & Zeeuw, 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. These checks can be very different and it has to be even 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 more constraints.

In other cases, e.g. when not all the required data is available, it is necessary to switch off some of the constraints defined in the conceptual data model.

In spring 2016 the development of an INTERLIS validation software called iliValidator was started through 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 found during validation are logged in a simple ASCII log file or in an INTERLIS transfer file based on a simple INTERLIS (“shape file level”) data model. With a configuration file (toml) the user can switch on/off the constraints or downgrade them to warnings instead of errors.

A really interesting feature is the use of iliValidator as programming library. It is then possible to integrate the data validation step in existing software, web services and/or existing processes.

4.2.5 QGIS LADM Project Generator and Editing Plugin

The LADM Project Generator and Editing plugin for QGIS, currently under development⁸, is a support tool to generate and edit data according to the LADM model. This means that the plugin will allow reading PostGIS data base schemas generated from any INTERLIS based LADM model, and provides the appropriate forms and data type widgets for the correct manipulation of data according to the classes, attributes, data types, relations and constraints defined in the model.

4.3 Interplay of the Tools

One of the most important things in the INTERLIS ecosystem is the interplay of all the different components. Thanks to its modularity, every tool does one or few tasks (“separation of concerns”), and the interplay of the discussed tools is very good. They can be easily coupled together, either as programming library or as simple system calls.

All the tools are open source. However, they can be integrated with a hybrid GIS environment (FOSSGIS and proprietary solutions) without violating the open source licenses.

An example of its interplay can be seen, when it comes to the documentation of the data model. The user can document all the classes and the attributes in the UML/INTERLIS-Editor. These comments will be exported in the conceptual INTERLIS data model. Ili2pg reads these comments from the data model and writes them in the database when creating the schema and tables. The QGIS plugin – as the last tool in this chain – will show these comments in the layer properties.

5. Development of a Web based Data Reception System

In the implementation of the Colombian profile of the LADM model, the concurrence with the pilot projects of the Multipurpose Cadastre executed by the National Planning Department (DNP) with funds from the World Bank is very important. The project supports the Cadastre Authority in developing a

⁸ The first functional version of the QGIS plugin is expected to be available by April 2017. The plugin is being developed collaboratively by Swiss and Colombian QGIS specialists.

system that allows the reception of data generated by the contracted surveying companies. This system could be easily employed by other land administration institutions.

The system consists of several modules, centralized around a web portal to access general information on the specifications of the Multipurpose Cadastre, news, forum and questions and answers, through a content manager. A dashboard of indicators allows users to follow the statistics on the progress of the implementation of the pilots of DNP, as well as the use of the system.

The system includes a web GIS module, to visualize the information generated and to support the Cadastral Authority in the manual verification process, as well as for the publication of data through different OGC standard services and for downloading model compliant data, in INTERLIS exchange format, available for other institutions, especially those related to property registration and mass tenure formalization processes.

Another important module is the document repository. It helps to manage all types of documents collected or generated during the pilot projects (contracts, deeds, field sketch, etc.). The module has the mission of managing all the documents that are an administrative or spatial source of LADM-COL, in which a reference will be maintained through the specialized classes of `LA_AdministrativeSource` or `LA_SpatialSource`.

The core module of the system allows the validation of INTERLIS data against the defined model before loading it into the database, and can be used by operators and supervisors of the pilot projects, as well as other entities that generate model conform data of the Multipurpose Cadastre. This implies a very important conceptual and technological advance for Colombia since, with more than 1100 municipalities and approximately 14 million registered properties in the country, only an automated validation process will allow this volume of information to be treated in an adequate and timely manner. It is clear that the defined and implemented validation process can also be employed once the maintenance of the Multipurpose Cadastre starts.

The development of the INTERLIS check service is done with the Java web framework Spring Boot⁹. All the validation logic is part of the `iliValidator` library, all the web service part is done by Spring Boot. In the end, the INTERLIS check service consists of a few lines of Java code. A functioning prototype¹⁰ was developed and will be adopted soon in the cadastre of the canton of Solothurn in Switzerland and by the Cadastre Authority in Colombia for the data which is acquired through the World Bank pilot projects.

⁹ <https://projects.spring.io/spring-boot/>

¹⁰ <https://git.sogeo.services/stefan/ilivalidator-spring-boot>

Non-LADM compliant data transformed to the official model by an Extract, Transform and Load (ETL)-Tool¹¹ can be validated, by including an iliValidator transformation step in the ETL process. The first ETL service is developed for the exchange of data of the Land Restitution Registry System with the Multipurpose Cadastre.

The last module of the system is a repository of data models in INTERLIS. When proceeding to validate a certain data set, the respective data model can be selected from this repository.

6. Toward the Construction of an SDI for Land Administration

The consolidation of a Multipurpose Cadastre within the framework of land administration requires full data interoperability to meet the objective of articulating and disposing updated land information to the different users (Williamson, Enemark, Wallace, & Rajabifard, 2009).

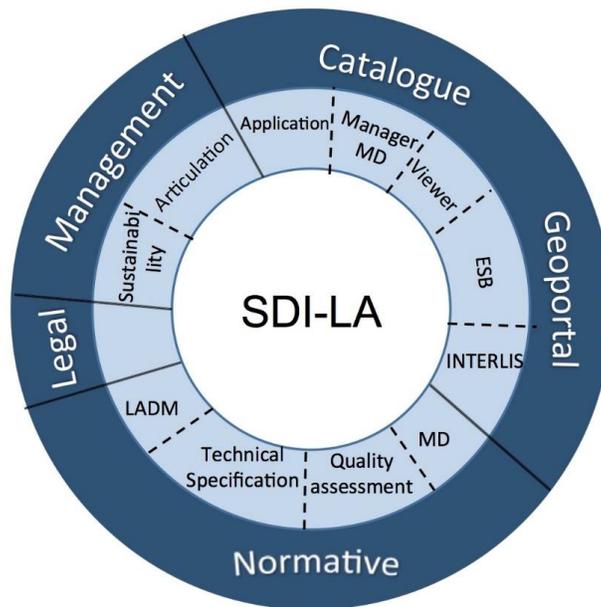


Figure 7. Conceptual framework of the SDI-LA.
Source: Project "Modernization of Land Administration in Colombia"

Efficient interoperability is also required if the principle of Legal Independence shall be fulfilled, where each institution assumes the responsibility for the management of its own legal land objects (Kaufmann & Steudler, 1998). The currently designed SDI for Land Administration (SDI-LA) by its future stakeholders and with technical support of the project (Figure 1), will be the articulating platform between all institutions with competences in land administration.

¹¹ Kettle (Pentaho Data Integrator), <http://community.pentaho.com/projects/data-integration/>

To achieve this goal, the Model-Driven Approach based on INTERLIS provides a feasible way for a seamless integration and consolidation of all land administration related data, just as in the case of the Swiss NSDI. INTERLIS is therefore part of the proposed conceptual framework of SDI-LA (Figure 7).

The currently developed Data Reception System for the Multipurpose Cadastre depicts the conceptual and technological basis for the construction of the future SDI-LA within the framework of the national ICDE.

7. Good Practices and Conclusion

The following lessons learnt regarding the LADM modelling and implementation can be considered:

- The process of modelling a LADM country profile should begin with a general decision for the Model-Driven Approach, followed by a consensus on a common set of initial definitions and agreements on the modelling approach, valid for all involved stakeholders.
- During the modelling workshops, the protagonists must be the thematic specialists of the involved institutions, guided by experts with previous experiences in the implementation of the ISO norm.
- It is recommended that the development of a country profile of the LADM is carried out individually with each institution, focusing in a first instance on Cadastre and Registry and identifying the semantic elements of the national context.
- The conceptual model of a LADM country profile is not an objective in itself, but a step in the implementation of the model. For this reason, improvement of the model continues until a good representation of the described reality is achieved, through an iterative work in interinstitutional modelling workshops. However the moment must be found to move on to the next phase where the conceptual model is described in INTERLIS.
- Appointing a special modelling working group on basis of an interinstitutional agreement could help to streamline the 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 new Multipurpose Cadastre in Colombia.

Regarding the INTERLIS based Model-Driven Approach (MDA) for implementing the LADM, the following considerations can be made:

- In Switzerland, although the Federal Act on Geoinformation of 2007 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. A freely available ecosystem of tools, which fulfills all the requested tasks of implementing the model-driven approach, is needed.

- These tools are now available as FOSS solutions and can be deployed and further enhanced if required, for any actual implementation of the conceptual LADM.
- The introduction of INTERLIS for implementing LADM must be accompanied by specific training courses in the language as well as in the application of the developed tools.

The defined, well-documented and successfully applied modelling process, methodology, INTERLIS base models and tools can be considered as an *LADM Implementing Toolkit* to be used by countries that face similar challenges as Colombia in modernizing their land administration.

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Figures

Figure 1: Thematic Areas and Model Driven Approach. Source: Project “Modernization of the Land Administration in Colombia”

Figure 2: Process and Methodology for defining the conceptual Colombian LADM Profile. Source: Authors

Figure 3: UML of the LADM-COL Profile. Source: Project “Modernization of the Land Administration in Colombia”

Figure 4: Modularization of the LADM-COL. Source: Project “Modernization of the Land Administration in Colombia”

Figure 5: Modularization of the current LADM-COL. Source: Project “Modernization of the Land Administration in Colombia”

Figure 6: Typical Workflow of an LADM Implementation based on INTERLIS Tools. Source: Authors

Figure 7: Conceptual framework of the SDI-LA. Source: Project “Modernization of the Land Administration in Colombia”