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## **EXTENDED MODELS FROM THE COLOMBIAN LADM PROFILE AS SUPPORT OF LAND USE PLANNING**

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## **Abstract:**

Colombia faces transcendental changes to define public policies related to land governance because of the Peace Process between the FARC and the Colombian Government. Among other initiatives, Colombia has been working on the construction of the Multipurpose Cadastral Data Model. This will help to define the expansion phase to the entire country, where the inter-institutional participation will be crucial.

The Project “Modernization of Land Administration in Colombia”, funded by SECO, has supported the Government in developing a Colombian profile of the norm (LADM-COL) and the building of the extended models for land administration, focusing on the land-use planning one (LADM-COL-OT).

The document presents the stages that have been identified and the tools that have been developed to define and put into operation the LADM-COL models based on INTERLIS and the challenges that Colombia will face to consolidate the concept of the modularity through definition, building and implementation of new models.

**Key Words:** Multipurpose Cadaster Colombia, LADM based on INTERLIS, LADM and SDI integration, Land Use Planning Data Model



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## SUMMARY

Over the last 3 years, SECO (swiss cooperation) funded project “Modernization of Land Administration in Colombia” is supporting the decentralization management of land administration data in Colombia in close cooperation with entities that have interests and competencies on land in Colombia.

Each institution uses their own model to store and manage the data needed to meet their own scope and needs, but this is done without a shared standard between them that permits the data interoperability. To solve this, the new Multipurpose Cadaster of Colombia defines the ISO 19152 (LADM) as a standard to achieve data interoperability. This standard should not only be seen useful for issues related to cadaster and registry. Beyond the land tenure, there are other important topics, such as environment areas, ethnic and ancestral territories, forestry, hydrology, national heritage and others. These themes will become part of the national profile of LADM (LADM-COL), composed of a basic core of common semantics and a set of extended models for the different areas of land administration.

Among the extended models, Colombia has a land use planning model (LADM-COL-OT) that has been defined with the participation of the project under the leadership of DNP (Planning National Department). This extended model is currently under validation by the governmental entities involved in this domain. The LADM-COL-OT shall be officialized to incorporate existing data and new data coming from the land use plans that are currently being developed

One of the priorities to implement the data interoperability policy is to create the Spatial Data Infrastructure for Land Administration (IDE-AT). This infrastructure shall have tools and functionalities that enable an environment of interoperability of data and services between the entities involved in territorial planning, and they have been designed under the “Modernization of Land Administration in Colombia”. These tools need to be tested and improved with real data coming from the Multipurpose Cadastre and the Land Use Plans to be implemented in the next years.



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## 1. INTRODUCTION AND BACKGROUND

Colombia faces transcendental changes to the definition of public policies related to land governance since the peace process between the FARC and the Colombian government that resulted in the “General Agreement to End the Armed Conflict and Build a Stable and Lasting Peace” (Acuerdo Final. 2016). Among other initiatives, the Colombian government decided to create the Modern Multipurpose Cadaster that integrates the planning and territorial information systems through the public policy document called "Policy for the Adoption and Implementation of a Rural-Urban Multipurpose Cadaster" (DNP. 2016) from the National Council of Economic and Social Policy (CONPES 3859 of 2016). The public policy proposes the adoption of international standards adapted to the Colombian case (ISO 19152 - LADM-COL) with the scope to integrate the information provided by the public entities related to land information to make it available for everyone, according with the open data policy.

Colombia has been working on the construction of the Multipurpose Cadastral Data Model (IGAC/SNR. 2016), and the evaluation of the first data set provided by the pilot projects is currently being developed. This will help define the expansion phase to scale up the methodology to the entire country, where interinstitutional participation will be crucial. Some of the main activities for the implementation of the modern multipurpose cadaster are development, building and implementation of the National Multipurpose Cadastral System, strengthening of the current cadastral systems for the administration and management of the cadastral information, execution of processes for data acquisition, update and maintenance of the cadastral information with a multipurpose approach and the inclusion of the social tenure plan for rural property with the participation of entities such as the Geographic Institute Agustin Codazzi (IGAC), Superintendence for Registry and Notaries (SNR), the National Land Agency (ANT) and the National Planning Department (DNP).

Currently, each institution uses their own model to store and manage the data needed to meet their own scope and needs, but do not have a shared standard between them that permits data interoperability. For this reason, the implementation of a Spatial Data Infrastructure for Land Administration (IDE-AT) is one of the priorities. This infrastructure shall have tools and functionalities that enable an environment of



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interoperability of data and services between the entities involved in the land sector (Gozdz. 2015) previously mentioned.

The standardization is based on the application of the Land Administration Domain Model (LADM) (ISO. 2012) and its adoption as a Colombian profile, called LADM-COL, considering the principle of legal independence and based on the Model-Driven Approach (MDA) (Mejia, et al. 2017). This proposal is based on the definition of several extended models on key issues related to land administration that should be articulated around LADM-COL.

The “Modernization of Land Administration in Colombia” project, funded by the Swiss Economic Cooperation (SECO), has supported the governmental entities in developing a Colombian profile of the norm (LADM-COL) based on the ISO 19152:2012 and the building of the extended models for land administration (Baron. et Al. 2017). In the specific case of the extended model for land-use planning (LADM-COL-OT), its conception implies a high complexity since it has a strong relationship with other issues related to affectations in the territory. In this context, another important concept is proposed: “The model’s interrelation”, which is described as the need to reuse information coming from different models (all based on LADM).

## **2. THE LAND ADMINISTRATION DOMAIN MODEL – ISO 19152:2012**

### **2.1 Basics**

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” (ISO. 2012).

It is important to understand the LADM as a conceptual model and not as a data product specification (Lemmen, et al. 2017). UML diagrams are commonly used to describe the LADM, which allows users to see and discuss the relationships between the administrative land objects (the BA-Units) and their structural components such as the parties, the rights, restrictions or responsibilities that a party might hold an



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administrative object and the spatial representation of the object. Thus, the LADM provides a standard based on a certain terminology of land administration, as described in ISO 19152:2012.

LADM is divided into a set of classes (Figure 1), grouped into three main packages (parties, administrative and spatial unit) and a sub-package (surveying and representation -spatial unit sub-package-).

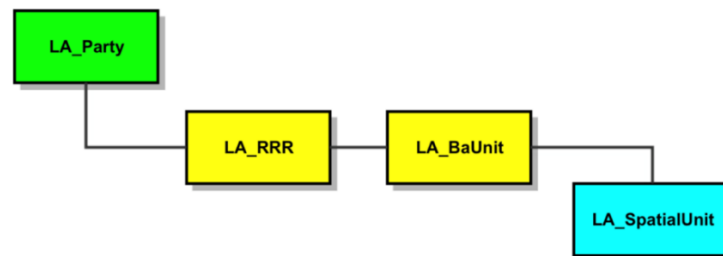


Figure 1 Main classes and packages of LADM

## 2.2 LADM - Colombian Profile

ISO 19152:2012 defines the Land Administration Domain Models as a reference for land administration. It shall be considered as a conceptual model instead of a data product specification (ISO. 2012) and emphasize its function as a generic domain model. It can then be extended with new attributes, operators, associations and even additional classes, depending on the needs of a country or a specific region, and provide an abstract conceptual model. In consequence, for the Colombian context, a national profile of LADM must be developed before its adoption.

Since September 2015, under the leadership of the swiss cooperation (SECO) and with the involvement of institutions, such as Instituto Geográfico Agustín Codazzi (IGAC), Decentralized Cadasters, Property Registry (SNR), National Land Agency (ANT), Land Restitution Unit (URT), and others, several workshops have been organized to develop the conceptual modelling process and the methodology for defining a Colombian LADM. These workshops have been conducted with the technical assistance of experts in the norm who moderated the modelling sessions with the local specialists.



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One of the main challenges in defining the Colombian profile has been the establishment of the core model (Baron. et Al. 2017) conceived as the fundamental part that holds all common classes related to land administration issues. This leaves in the core model the very basic definition of ISO 19152, a set of abstract classes that establishes the main concept of the elements that participate in any extended model of LADM.

This legal independence requires that each institution assumes the responsibility for its own data and an adequate way to guarantee interoperability. However, ISO 19152:2012 does not describe how to manage these sets of legal spatial objects, so that the achievement of this objective cannot simply be delegated to LADM (Bajo. et Al. 2017).

In this approach, the “Modernization of Land Administration in Colombia” project, together with the Colombian government, promote the concept of modularity of LADM (Bajo. et Al. 2017). Each topic of land administration consists of separate models all based on the same core model (LADM-COL) and include geometry data type defined on ISO 19017. This concept allows each institution to work with its own legal spatial objects within its competence according to the current legal framework. In this way, all the resulting modules per topic (Figure 2) are created around the same ontological principles and the same semantics defined by LADM.

The current LADM\_COL profile is composed of the following models:

- the ISO 19107:2003 model, containing the description of geometries and the definition of reference system and coordinate range.
- The ISO 19152:2012 model in its original language (English);
- The ISO 19152:2012 model as a Spanish translation, maintaining the reference to the elements of the English version using the official translation of the Spanish Normalization Agency AENOR (UNE-EN ISO. 2013)
- The Core or Minimal Model, defined by identifying the elements of the national LADM-COL profile that are common to the institutional needs
- Extended thematic models: All classes, domains, attributes and relationships outside the core grouped by topic are considered extended models.





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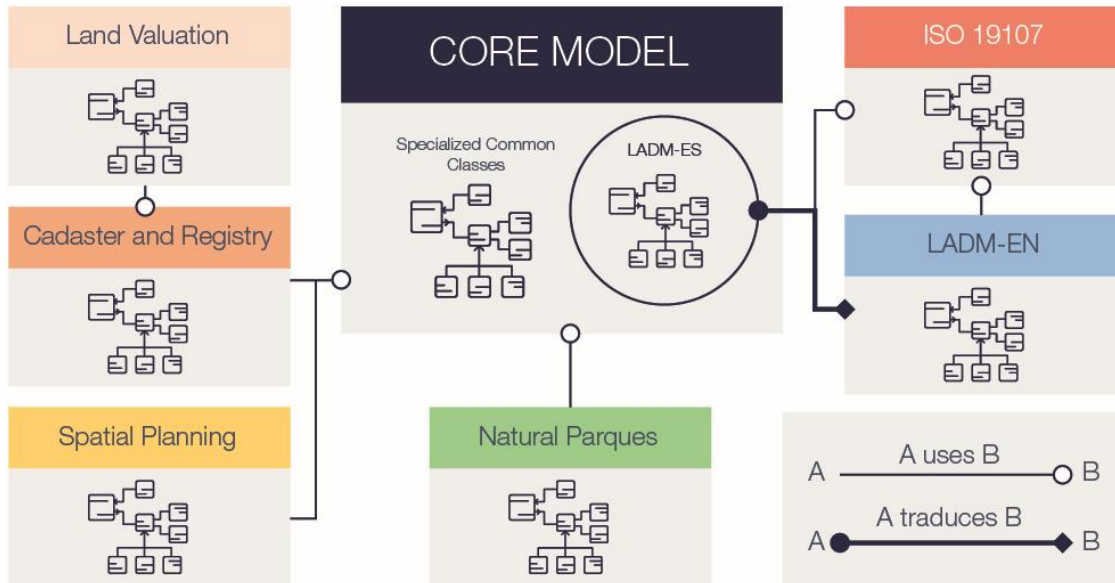


Figure 2 Modules in the LADM-COL

As a result of the building of extended models related to land administration in Colombia, the following stages have been identified and the tools developed that allow the definition and operation of these LADM-COL extended models based on INTERLIS.

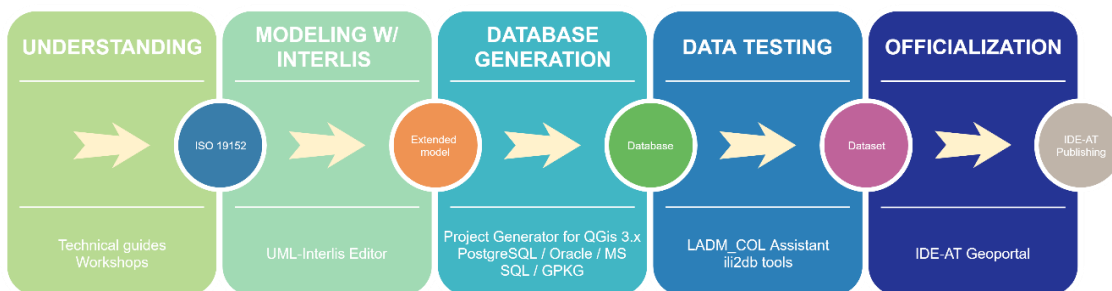


Figure 3 Principal stages for defining extended models of LADM

### 2.3 Use of INTERLIS to describe extended LADM Models

INTERLIS is a conceptual schema language (CSL, synonym of Data Description Language), oriented to objects and independent of platforms and systems (KOGIS. 2006); used for the formal description of





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relational or object-oriented data models. Compatible with UML and XML, that allows to create data models and exchange data according to these models.

In the field of data transfer, INTERLIS, performs the exchange based on a specific data schema (data model described also on INTERLIS), sending a set of data according to the selected data model, structured according to the tables, relationships they maintain and the restrictions they are subject to; such as data types, valid value domains, if null values are allowed or not, etc., allowing also to customize these restrictions, even of topological type (Bajo. et Al. 2017).

All these advantages made INTERLIS the “perfect Match” (Kalogianni, et al. 2017) for implement LADM based models, has been adopted so far by the Colombian institutions and the INTERLIS LADM-COL model is now part of a set of product specifications for the Multipurpose Cadaster.

### 3. TERRITORIAL PLANNING MODEL

Colombia is divided into 1102 municipalities, which are responsible for defining their own land use plans every 12 years. Those plans are the basic tools defined by the 388 Law of 1997 and are conceived to order human occupation in each part of the territory. In practical terms, land use plans defined so far lack standardized criteria, having even different conceptual bases, and this is the reason why the use of LADM is required: to unify semantics and ontology around land use planning in Colombia. Furthermore, it is possible to reuse the tools developed by the “Modernization of Land Administration in Colombia” project in coordination with IGAC, ANT, SNR and DNP, on the framework of the new Multipurpose Cadaster pilot’s projects funded by the World Bank. Those tools allow the definition of a conceptual model described in INTERLIS and to capture, edit and exchange data using standardized formats following the semantics established by LADM.

The proposed Land Use Planning Model (LADM\_COL\_OT) ,shown in Figure 4, is conceived to formulate the Land Use Plan (not the diagnostic) and includes the main information of Land Use Plans according to the Colombian regulations (Law 388-1997, Law 1454-2011, Decree 1077-2015) (Zabala, 2018). This model is based on the LADM standard elements: Basic Administrative Units (BA-Units), spatial units,



rights, restrictions and responsibilities (RRR), stakeholders (Party) and Sources. Current version of the LADM\_COL\_OT model is available on [https://github.com/AgenciaImplementacion/LADM\\_COL](https://github.com/AgenciaImplementacion/LADM_COL).

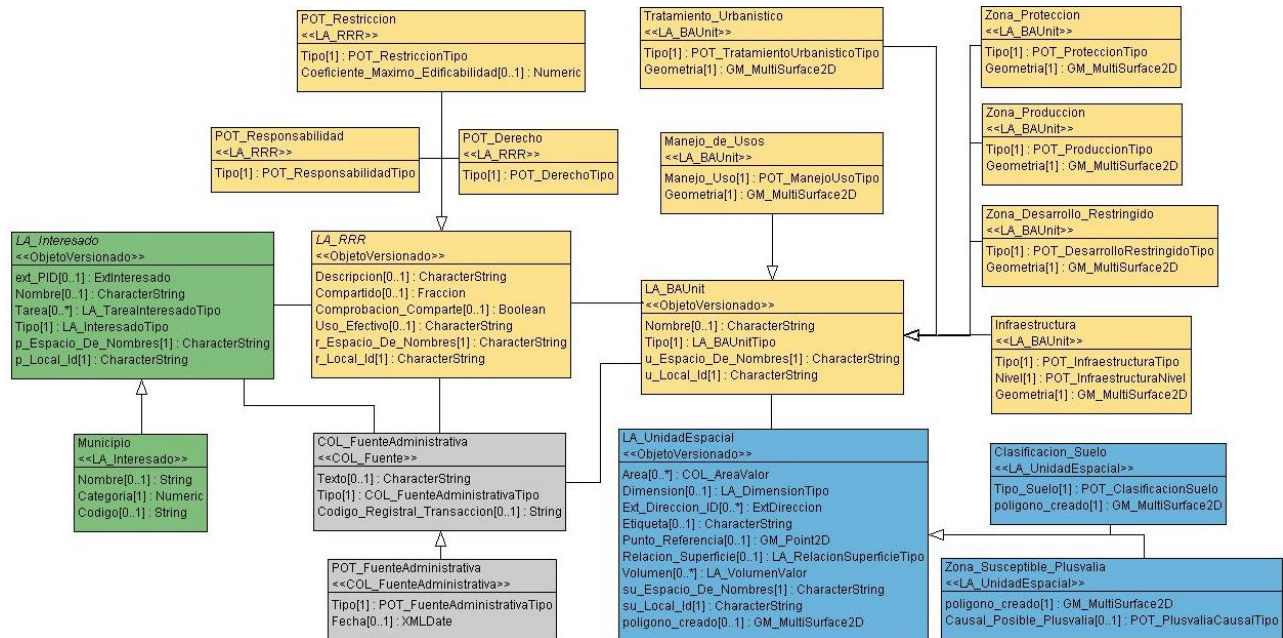


Figure 4 Land Use Planning Model described in UML

Several basic administrative units are defined, because different area types defined within a plan, have different effects on the land use through rights, restrictions and responsibilities. The municipality (Municipio) was defined as the main interested party, because it is the municipality which authorizes or forbids actions by public or private entities on their territories.

At the level of rights, restrictions and responsibilities, the Land Use Planning Model should consider the different basic administrative units defined, and the defined domains contemplate all the possible RRRs that may exist on each of the basic administrative units, considering the hierarchy of restrictions. For instance, restrictions established by protection areas are more significant (more restrictive) than restrictions supposed by other BA-Units.



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Finally, in the Land Use Planning Model, sources are established as documents required for the plan, such as norms, decrees, and mainly the final document for the period formulated (According to Colombian Law, it must be renewed every 12 years but can be updated yearly).

## 4. MODELS INTERRELATION AND THE SDI FOR LAND ADMINISTRATION

Currently, Colombian entities use data modeled by themselves without attending to a single standard and without the possibility of efficiently interoperating with other institutions. For this reason, the construction of a Spatial Data Infrastructure for Land Administration (SDI-LA) is one of the main priorities. This SDI shall have tools and functionalities that enable interoperability of data and services between the entities, and it shall be focused on the citizen.

SDI-LA is a thematic node of the Colombian Spatial Data Infrastructure (ICDE) and should be an entry point where different users interact with a universe of resources, services and applications, based on the need to facilitate access and use of territorial information.

Thus, the different models of land administration converge in the SDI-LA environment, where the objects administered by a single theme can serve as an input to create new objects for another theme of the land administration (e.g. river flows are the main input to define hydraulic rounds and their environmental protection areas. Each of these levels of information is defined in an independent data model and is managed by different entities). Also, existing objects in a data model can suppose limitations/conditions for the establishment of activities that are mapped in another model (e.g. indigenous lands and ancestral territories are areas where the development of commercial activities, such as mining or extensive agriculture, is not allowed. In consequence, areas defined on indigenous reserves model will be a restriction on land use, defined in the use planning model).

Figure 5 shows how the information contained in the cadaster-registry model (left) is linked to the Land Use Planning Model (right). Using one spatial query, it is possible to obtain a report of restrictions and responsibilities falling into a given parcel



The information contained in both models is stored by independent entities, using independent data models and even different technologies, but thanks to the implementation of an SDI, it is possible to access the information using standardized exchange formats. In addition, a new concept called interrelation between models is applied. Previously, it was common to talk about crossing geographic layers, but now that it is a complex issue (such as territorial ordering) it is not enough to cross two layers because there is information beneath the layers that should be considered in the moment of the analysis. It is not enough to know which area of ordering covers a plot and how much area is affected. It is necessary to know which rights and restrictions are imposed by the given ordering zone; this can only be achieved through the interrelation between models. Thanks to the use of standardized LADM semantics, it is possible to navigate between the different relationships among the BA-Units and the RRRs defined for each model.

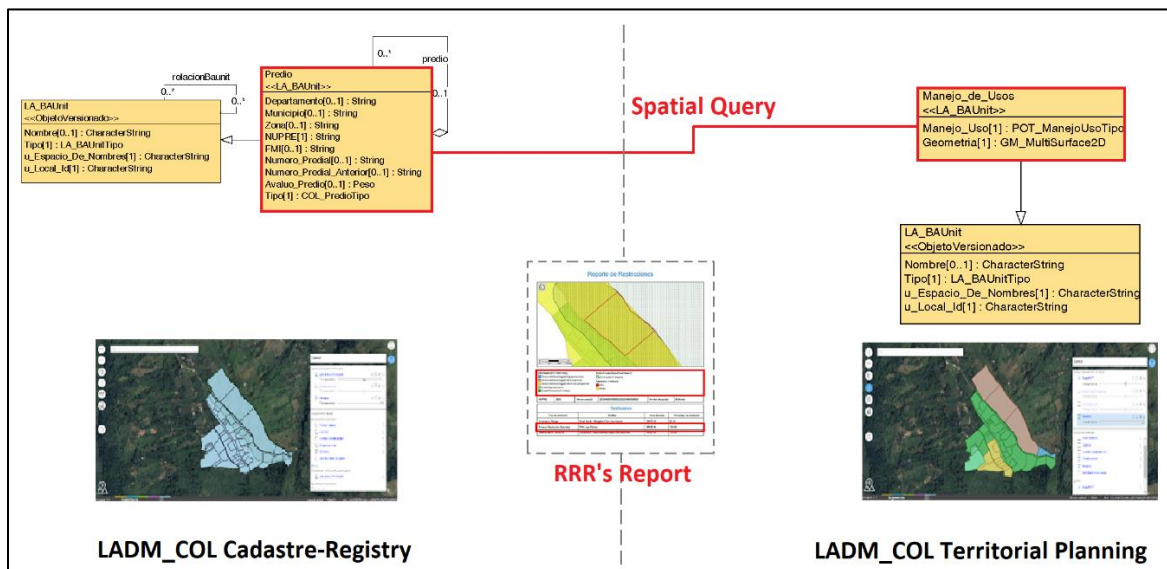


Figure 5 interrelation between LADM-based models

## 5. FOSS TOOLS FOR IMPLEMENTING LADM EXTENDED MODELS DESCRIBED ON INTERLIS

In support of the implementation of the LADM - COL standard, a set of free and open source software (FOSS) tools have been developed. They have been designed to supply the needs of the governmental entities involved in the process of data acquisition, data management and data exchange related to land



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administration (Jenni, et al. 2017). These tools are, on one hand, those that facilitate the work with models (creation of conceptual models, their compilation and their loading as a physical model in a database) and, on the other hand, those that allow data processing (massive load, massive validation, import and export).

The following figure illustrates a conceptual generic workflow of model's implementation using INTERLIS, starting from the definition of the model itself in a conceptual language and its transformation to a physical database model. This is followed by the structuring/loading of data, and it ends in the data transfer and validation according to the given model.

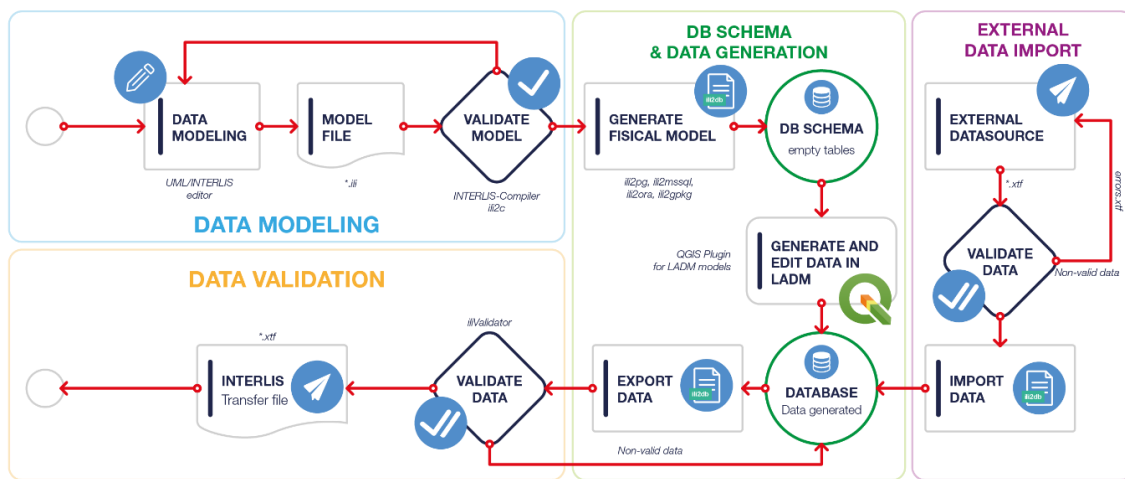


Figure 6 Interlis Workflow

¡Error! No se encuentra el origen de la referencia. describes each tool and its role into the typical conceptual INTERLIS workflow implementation. These tools are free and open source, and its source code is published on the Project's GitHub Page (<https://github.com/AgenciaImplementacion/>).





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<i>Tool</i>	<i>Functionality</i>	<i>Language</i>
 UML/Interlis-Editor	Modeling in UML and conversion to an INTERLIS model file *.ili	Java
 INTERLIS-Compiler ili2c	Validates the syntax of the .ili files, produces other output formats.	Java
 ili2db (ili2pg, ili2gpkg, ili2sqlServer, ili2ora, ili2fgdb )	Used for O/R mapping of object-oriented models to a relational DB schema; import and export DB data to (XTF) Interlis exchange format	Java
 QGIS Plugin “Project Generator”	Generates interfaces and forms to edit data according to the model including domains, relations, constraints and data types	Python, C++
 QGIS Plugin “Asistente LADM-COL	Assits in the workflow of generating model-conform data, data querying, quality checks and printing/reporting.	
 iliValidator	Validates the integrity of data to be exchanged with the rules and constraints established in the model (including topological constraints, etc.).	Java

Table 1 Tools and functionalities for implement INTERLIS-based models

The described tools were integrated in a web-based system, consisting of several modules and independent services that provide massive and automated validation, DB import, query, visualization and data download functions. To comply with the MDA approach, the core of the system are the thematic models of the LADM-COL, stored in a repository of official models; the interfaces and forms of the modules are adjusted semi-automatically to each model. This considerably reduces the development phase and emphasizes the design (**¡Error! No se encuentra el origen de la referencia.**)



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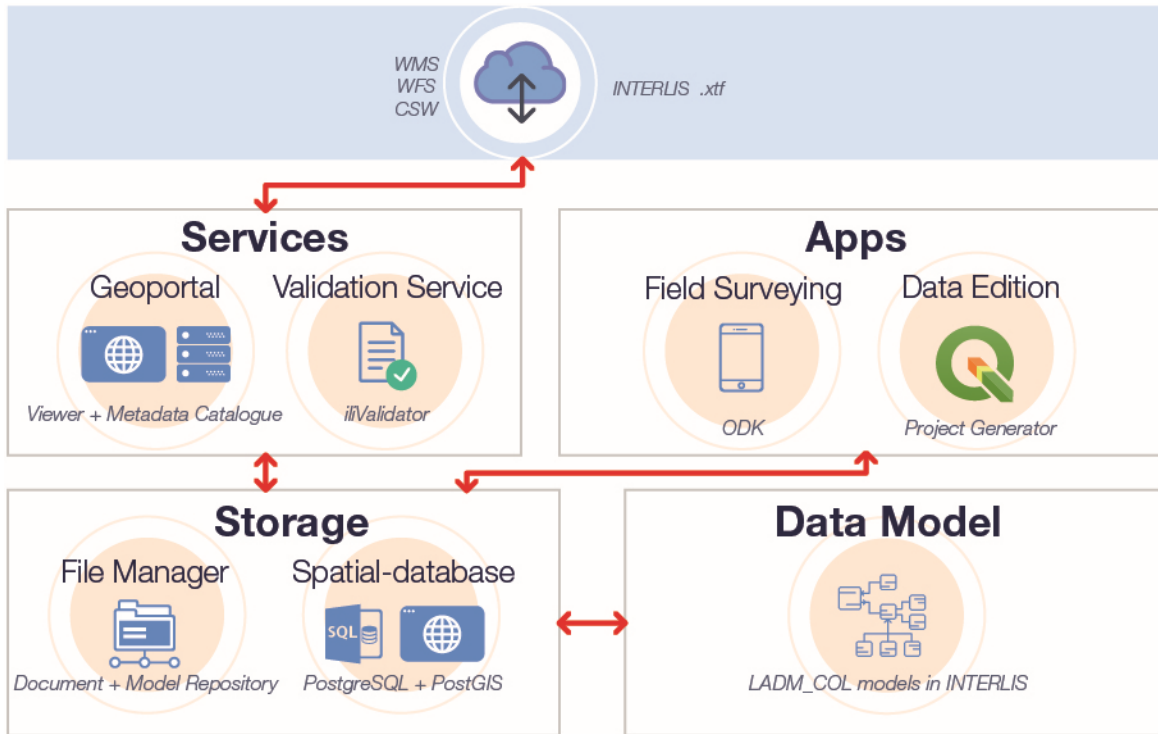


Figure 7 Typical components on an LADM web-based system

The following diagram shows the value chain of the data in a decentralized operating environment applied to any topic of land administration.

In this case, the existence of two main actors is assumed. Firstly, a public or private operator that performs the activities of data collection, structuration and delivery, and on the other hand, a land administration public entity, in charge of receiving, validating and publishing the data according to its competence.

Principal steps for both actors and tools proposed by the Project are shown in **¡Error! No se encuentra el origen de la referencia..**





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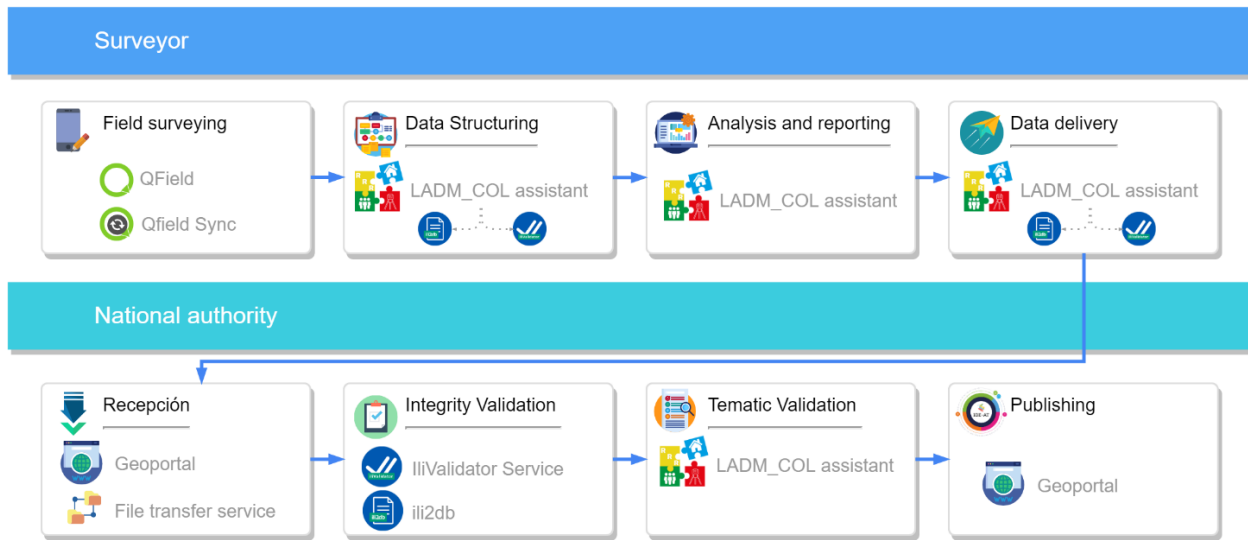


Figure 8 Workflow in a decentralized operating environment

## 6. CONCLUSIONS AND RECOMMENDATIONS

The adoption of the ISO 19152 LADM as standard and the implementation of the concept of modularity based on the legal independence principle, composed of a basic core of common semantics and a set of extended models for the different areas of land administration is facilitating the achievement of data interoperability among entities involved in the land administration.

To facilitate data interoperability between institutions, the data reception system presented can be easily implemented by administrations with limited resources (e.g. municipalities) and can be considered as a generic information infrastructure of Land Administration, with LADM as the underlying model.

The INTERLIS tools ecosystem is now available and enables the development of an information infrastructure based entirely on an MDA approach. This facilitates the implementation of any LADM country profile including its extended models.



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The swiss cooperation, together with the National Planning Department (DNP), has defined a land use planning model (LADM-COL-OT) that is currently under validation by the governmental institutions involved in this domain. This extended model shall be officialized in order to incorporate existing data and new data coming from the land use plans that are currently being developed. This will permit to consolidate the adoption of the LADM-COL and its modularity concept, as it will facilitate the integration and articulation between the different sectors (environment, housing, agriculture, culture) and its impact on the territory.

Our main recommendation is to continue working on the development of new tools and services that will improve the LADM-COL implementation, specifically with land use plan model (LADM-COL-OT) and multipurpose cadaster (LADM-COL-CATREG) and we encourage the Colombian entities to work in the use of this tools that will facilitate the data interoperability under Spatial Data Infrastructure for Land Administration (SDI-LA).



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