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A 3D LADM Prototype Implementation in INTERLIS

Eftychia Kalogianni, Efi Dimopoulou and Peter van Oosterom

Abstract The massive developments and uses of high-rise buildings indicate that the demand for use of space above and below the ground surface is rapidly increasing in recent years. The same applies to Greece, where the existing cadastral model does not cover the 3D needs and does not conform to international standards. In this paper, a model is proposed, considered as an effort for overcoming these shortcomings, based on international standards, including the representation of a wide range of different types of spatial units, organized in levels according to the LA_Level structure of ISO19152 LADM. It is a proposal for a comprehensive multipurpose LAS supporting 2D and 3D cadastral registration in Greece. A prototype system was developed to exploit the strengths and limitations of the proposed conceptual model, as well as to investigate the efficiency of technological tools. Experience from the prototype will be used to further improve the conceptual model. The steps that were followed were: the description of the prototype in UML diagrams, the implementation via INTERLIS, a Swiss standard modeling language for geodata exchange, the selection of the most appropriate technical model/format to implement and visualize the result in 3D environment and finally the conversion and/or creation of sample data into the model. In this paper it is explored how INTERLIS can be used in actual implementation of land administration system based on LADM. During the development of the prototype many design decision have been taken and these are then analyzed, together with technical problems and challenges for future work.

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1 Introduction

Competition for space resulting from population growth, limitations of land supply for infrastructure developments in urban areas together with the complicated use of space led to the development of multi-level and vertical constructions. All those developments not only increase the complexity of urban environments, but also affect land property ownership interests attached to the underlying land (Aien and Rajabfard 2014). The complexity of the property ownership interests cannot be sufficiently addressed in all situations by the existing 2D cadastral systems. For that reason, 3D Cadastre has been introduced as a solution to this problem and FIG decided to establish a 3D Cadastre Working Group to make further process (van Oosterom 2013).

The key for successful management of uses and ownerships of property objects and spaces above and below the ground and their corresponding uses and ownerships rights is the availability of a reliable information system with a multipurpose character. Such information system is expected to be able to handle information related to 2D and 3D geometries and their corresponding attributes that reflect complexities of rights, restrictions and responsibilities of 3D objects (Budisusanto et al. 2013).

A Multipurpose 3D Cadastre can be defined as an integrated land information system containing legal (e.g. tenure and ownership), planning (e.g. land use zoning), revenue (e.g. land value, assessment and premium) and physical (e.g. cadastral) information (Choon and Seng 2013). Under this concept, the need to organize all the information related to land registries in one model and enable transparent geo-information exchange is growing.

The development of multipurpose land administration systems (MLAS) is a complex task. Taking this situation into account, there is a need to standardize the process of land management, introducing models for the effective management of the properties and the property rights attached to them with a multipurpose character.

Land Administration Domain Model (ISO 19152 2012), 3D Cadastre Data Model (3DCDM), SDTM and ePlan (2010) are some modeling approaches concerning how 3D MLAS can be based and organized accordingly. Those cadastral models manage and maintain 3D land and property ownership interests (including 3D RRRs) and represent legal objects. However, one of the most important elements of a cadastral model is the ownership boundary. Since ownership boundaries are often represented by building's physical structures, such as walls and floors, cadastral data model should relate—or even integrate—both legal and physical objects of urban features (Aien 2013).

Towards this integration, the derivation of a technical model from the conceptual is key challenge. Nowadays, many tools have been developed in order to facilitate and automate this conversion. Enterprise Architect, a UML modeling tool from Sparx Systems, and INTERLIS, a SWISS standard that allows co-operation between geographic information systems, are two of the most significant tools in this domain (COGIS 2006).

Based on the points mentioned above, this paper deals with the development of a prototype of 3D multipurpose land administration system that is capable to facilitate the registration of multi-level and multi-use property spaces using LADM principles and comply with national law. The methodology is implemented for Greek cases and in particular, for a comprehensive land administration system based on LADM for 2D and 3D cadastral registration system. The model takes into account the existing spatial and administrative registration systems in Greece, and is partly based on new developments inspired by the LADM standard and its implementation in other countries.

The main focus of this paper is to describe how a technical model, a database schema (SQL/DDL) or a data exchange format (GML, XML, etc.) can derive from the conceptual model described in UML class diagrams and discuss how reliable this conversion can be by using existing tools.

The remainder of this paper is organized as follows. Section 2 elaborates the basic modeling principles, the current standardization options on the land administration domain and the interaction between multipurpose land information systems and the current standardization developments.

Section 3 provides the steps on the development of the prototype, elaborates the materials and methods used in each step and discusses the result. Finally, Sect. 4 summarizes the paper concluding the major findings and proposes future development of the prototype.

2 A 3D Multipurpose LAS

2.1 3D LAS Standardization Options

Significant progress has been made in advancing the concept of 3D cadastres and related technologies to facilitate their realization. These advances have been gaining momentum: over the last few years, the endorsement of different standards has occurred, and jurisdictions that currently develop prototype systems and undertake pilot trials to test conceptual boundaries and appropriateness significantly increased.

After prior research and prototype developments, a new era has arrived with the implementations and pilot programs of the first 3D cadastral systems in operation. Therefore, the use of existing standards and shared-terminology and concepts are key challenges towards this direction (van Oosterom 2012).

Standardization is a well-known subject since the establishment of LAS; even since paper-based systems existed. Over the last years, a lot of research has been conducted in the domain of standardization regarding land administration practices. Many standards all over the word have been developed dealing with the modeling of the whole system, the data types, the metadata, the geometry types, the representation, etc. However an international standard for land administration systems didn't exist.

Land Administration Domain Model, ISO19152, was introduced as a model to create standardized information services at an international context, where land administration domain semantics have to be shared between regions or countries, in order to enable necessary translations. It is a simple model with flexible and extensible elements based on the pattern "*people—land*" relationships.

The LADM was approved as an official International ISO Standard on November 1st (2012). It covers basic information-related components of land administration (including those over water and land and elements above and below the surface of the earth). The model provides a conceptual schema with three basic packages (Lemmen 2012):

1. Parties, which means people and organizations that perform transactions,
2. Basic administrative units, including rights, restrictions and responsibilities,
3. Spatial units, mostly parcels and the legal space of buildings and utility, including the sub package "*surveying and spatial representation (topology and geometry) and spatial sources*".

LADM covers land registration and cadastre in a broad sense by describing spatial and administrative components, source documentation and the ability to link with external registrations, such as physical object registration (buildings, utilities, etc.). The model also includes agreements on data about administrative and spatial units, land rights in a broad sense and source documents (e.g. titles, deeds or survey documentation). The rights may include real and personal rights as well as customary and informal rights and the restrictions and responsibilities can be similarly represented to document the relationships between people and land.

Recent works suggest that the utilization of LADM international standard for cadastral domain is significant as mentioned by several researchers: Lemmen (2012), van Oosterom et al. (2011), Pouliot (2011), etc. Many countries such as Poland, Republic of Korea, Malaysia, Indonesia, Croatia, etc. have proposed country profiles based on LADM. A key challenge is to include the third dimension in such models and develop prototypes that can support it.

With the maturation and accessibility of 3D technologies, there is little doubt that we are now moving to embrace a 3D digital environment for land administration business practices, including an object-oriented approach to managing information about land and property RRRs (Rajabifard 2014).

There are many formats for the storage and visualization of the spatial data, some focusing on the description of geometry (e.g. InfraGML, X3D Scarponcini 2013) and some others also including the representation of semantic and thematic properties and aggregations (Kolbe 2009) (e.g. CityGML). Exploring opportunities for leveraging 3D technologies, such as the use of Building Information Models

(BIM), Industry Foundation Class format (IFC) (IAI 2008) and CityGML facilitates greater collaboration around the function of 3D Cadastres.

In this direction, apart from international standards, national standards have also been developed. The most representative standard in this category is INTERLIS (Germann et al. 2015). INTERLIS is a standard for the modeling and integration of geodata allowing co-operation between information systems, especially geographic information systems, see Fig. 1. It is a Conceptual Schema Language (CSL) and a neutral transfer format and also defines a system neutral XML based data exchange format. Using its tools (e.g. compiler, checker) it is possible to quality check INTERLIS data and is compatible with the most relevant international standards (UML, XML, XML Schema, GML).

INTERLIS is an Object Relational modeling language, a very precise, standardized language on the conceptual level to describe data models. Both humans and computers can read it and it has built in data types for GIS; e.g. the geometry types. Transfer formats are derived from data models by transfer rules and there is strict separation of transfer and modeling aspects (model driven approach).

The main benefits from INTERLIS are that it:

- Supports freedom of methods through system neutral approach;
- CSL is easily understandable by IT and domain experts;
- Data can be directly processed and checked by computers;
- Allows for automated data quality control (checker, check service);
- Allows the automation of many cadaster related processes;

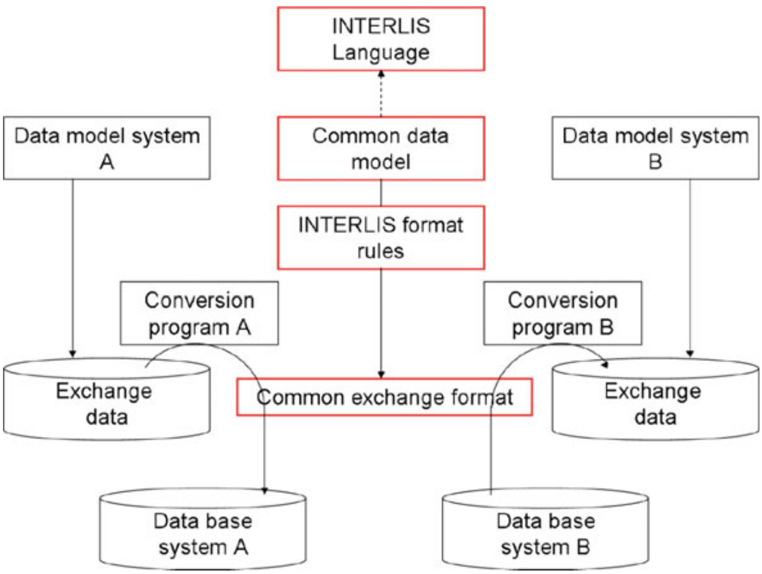


Fig. 1 INTERLIS (COGIS 2006)

- Has built-in geometric data types (point, polyline, polygon), making it especially suitable for models in the geo-information domain.
- Provides reference manuals, translated to many languages.

Furthermore, it has relation with other standards. INTERLIS uses UML as graphic representation of its data models (.ili files). Moreover, GML is supported by INTERLIS through additional transfer rules (eCH—0118 2011). In particular, INTERLIS allows INTERLIS (.ili) and XMI files to be imported and SVG, JPEG, INTERLIS, WMS and XML Schema files to be exported from INTERLIS tool chain (Germann 2015).

The last years, there is a growing interest in the implementation of conceptual models into technical. By describing a conceptual model with a tool based on CSL and then derive the technical model results in (directly) implementable model descriptions based on the conceptual models. Therefore, the description of LADM with INTERLIS enables the exchange of LADM data between IT systems, which can be used to initialize databases or transfer LADM data via XML.

2.2 A 3D Multipurpose Land Administration System for Greece

The implementation of the tools mentioned above is done using a 3D multipurpose LAS proposed for Greece based on LADM, in order to derive the technical model from the conceptual. The party and administrative package of this model together with an overview of the spatial part, described in UML is presented in Appendix II.

Greece presents several deficiencies in adapting with international requirements and best practices. The Hellenic Cadastre (HC) is still an ongoing project relying on its data model, not conforming to international standardization criteria. This model presents heterogeneity concerning geospatial data and cannot act as reference base for National Spatial Data Infrastructure.

In this paper, the proposed model is considered as an effort for overcoming previous shortcomings, introducing a model based on international standards, covering a broader perspective than the one of the National Cadastre and Mapping Agency SA (NCMA SA), including objects and interests that are not registered to the existing model. More precisely, networks (both the legal and their physical part), planning zones, marine parcels and 3D parcels are not included nor provided by the existing model.

Greek planning law comprises a wide range of instruments which extent from strategic plans at national level to regulatory town plans and zones at local level. Therefore, planning zones are very important as they define activities, policies, land uses and restrictions for the entire country and it was considered necessary to be included in this model. On the other hand, marine parcels are not recorded in the

HC today, despite the fact that sea covers a big part of the Greek territory. Because the model is future-proof it was considered necessary to include marine parcels as a separate level.

Conforming to a standard like LADM would reduce time for new data production, the number of people and resources, while land transactions would be safer and of higher-quality and data update would be assured. Technically, the structure of LADM supports 2D and 3D cadastral registration of legal items and the link with their physical part. The following paragraphs analyze the need for a multipurpose land information system in Greece, organizing in groups the wide range of different spatial units and drawing the attention on the third dimension.

The land question and RRRs in Greece present great diversity and specificities, as it largely depends on localized historical, economic, social, political and cultural factors. At this model, an attempt is made to cover all Greek land administration related information, which is maintained by different organizations today. Despite its small surface area, Greece is endowed with a particular rich and diversified natural environment; with unique geomorphology and intense contrasts. All those diversities conclude to complex scenery, with different characteristics, which should be registered and managed into a coherent and unified system. Moreover, the rights, restrictions and responsibilities attached to that scenery, the activities developed, the responsible parties, as well as the difficulty to represent the outline of it need to be described explicitly.

Therefore, the 3D MLAS should contain information about administrative records, tenure, value and sale and purchases records, base maps, cadastral and survey boundaries, categories of land use, streets addresses, census utilities, all rights, all parties etc.

A new data model could facilitate the provision of data to internal and external users in a more flexible format for the community's needs. That means improving the structure of property rights, restrictions and responsibilities, as well as all relative stakeholders, in a direction of harmonizing with international land administration systems and standardization processes in this field. In order to improve insight in the spatial component of rights established on 2D parcels, the current system needs to be extended and introduce the registration of 3D situations. In order to make the model comprehensive and future proof, all spatial units can be supported in such a model, even if not supported today by the NCMA S.A. or another organization.

But why registering the third dimension?

The implementation of a 3D cadastral model in Greece is specifically required for the registration of SPROs (but also for other types of spatial units with RRRs attached as mines, marine parcels, utility networks and even "normal" parcels, 3D will be more important in the future, see Appendix II). The SPROs are currently the only registrations with 3D tags in the existing model. They include very common cases in several Greek islands where land parcels and buildings are partially or totally overlapping to each other. A 3D challenge demonstrates in Fig. 2, where anogia and katogia (typical SPROs) are represented in Santorini Island with steep slope, where most houses are dug in the volcanic soil led to overlapping properties.

Fig. 2 Special property right objects in Santorini Island (Dimopoulou et al. 2006)

Recent work (Tsiliakou and Dimopoulou 2011) (Fig. 3) has shown that those characteristic cases need the description of the third dimension and the visualization of the physical objects on 3D environment is of a great importance.

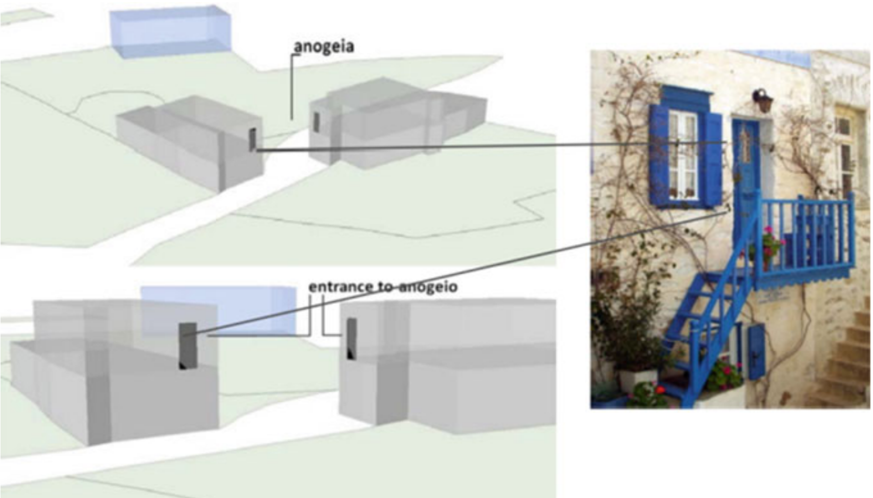


Fig. 3 Anogia in Syros Island (Tsiliakou and Dimopoulou 2011)

3 From Conceptual to Technical Model

3.1 Prototype Development

Towards the implementation of the prototype, the creation of the conceptual model is followed by the transformation of the logical data model into a physical database. Through this conversion, many implementation and design decisions have been taken, from the conceptual understanding of possible errors or duplicates at the proposed model, to the selection of the most appropriate DBMS.

The paper also introduces the implementation of LADM with INTERLIS following the methodological steps discussed in (Germann et al. 2015), drawing particular attention to the formulation of constraints and the 3D, as until now this wasn't included. The main purpose is to investigate the process of deriving a database schema or an exchange format from the conceptual model (UML diagrams), using technological tools, which support the initial attributes, constraints and aggregations.

Figure 4 presents the methodological concept followed during the development of the prototype. As a first step the 3D multipurpose LAS was described in UML diagrams using Enterprise Architect software. The UML model was exported in XMI (XML metadata format) in order to be imported in INTERLIS. However, due to a compatibility problem, this conversion was not successful.

Therefore, the conceptual model was (manually) described in INTERLIS language. The INTERLIS model was imported into INTERLIS compiler for quality check. Real data concerning both the legal and physical aspects of the object has

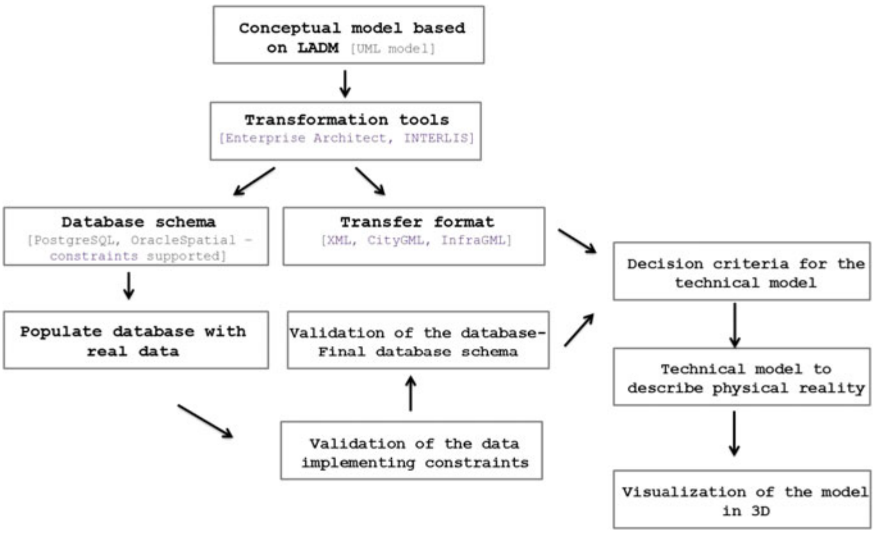


Fig. 4 Prototype development: methodological steps

gathered from the responsible authorities and populate the database. The data refers to the majority of the levels created in the spatial part of the proposed model mostly concerning condominiums, 2D rural parcels, archeological spaces, mines, polygons created from planning zones and data for utility networks.

The next step is to visualize the result with physical objects. There is a plethora of candidates to describe the physical reality of the data; CityGML, IFC, LandXML, InfraGML, etc. For that reason four decision criteria were set in order to choose the appropriate one, as presented below:

- Is it used? Do we have real data available?
- Will it be maintained in the future? Is there a Consortium/Institution responsible for maintaining this format?
- The data we want can be described within that model?
- Is there a conversion to XML available or possible? As XML-based format has become the default for many tools, it has also been employed as the base language for communication protocols, which means that it is compatible with most of the existing formats.

Based on those criteria, CityGML and IFC are considered to be the two most appropriate formats to describe the physical reality of this model. Both formats fulfill the requirements set by the criteria described above and also support semantics. However, the two standards have different concepts, i.e. they represented the building structure from two distinct views: the constructor (IFC) and the user (CityGML) view. Which model is more appropriate to be used for the physical description of this model is further to be studied in detail.

In recent years, various 3D visualization solutions have been developed, some of them web-based. Shojaei et al. (2014) at their study summarize the common 3D web-based solutions and compare them and their conclusions are helpful towards the selection of the best candidate format.

Another aspect that is of great importance and requires formal description is the constraints of the model. Constraints are often initially described in natural language; however practice has shown that this results in ambiguities. For the prototype, constraints have been defined from the first step of a prototype in order to reduce complexity.

According to Paasch et al. (2013) constraints can be categorized as: constraints derived from the properties of objects (thematic, temporal, spatial and mixed constraints), constraints derived from spatial relationships between objects (thematic, spatial, temporal and mixed) as well as constraints grouped according to their dimensional aspects (constraints that concern the 2D ground plane and/or the 3D objects).

In this paper, the constraints are defined on the UML model using the Object Constraint Language (OCL), which enables to express the constraints at a conceptual level in a formal way. EA supports OCL syntax on the model and also supports the ability to validate the OCL statement against the model itself. This means that it enables the verification beyond just the syntax that the OCL statement is expressed correctly in terms of actual model elements, and that the kind of validation syntax that it uses corresponds to the actual data types defined for these elements: numbers, strings, collections, etc.

Database implementation offers better management of constraints. The types of constraints that can be found in a database are unique constraints, referential, primary key and check constraints. Those are useful but not powerful enough to support all the spatial constraints. For that reason, the use of triggers is proposed as an alternative solution for general constraint implementation in DBMS.

For the proposed model there are many types of constraints that can be found, i.e. primary key must be unique, end date of unfinished construction must be equal to start date of a building, if there is a co-ownership in a parcel, the sum of the RRR share should always be 1, boundary of 2D parcel must be closed, if we refer to the marine parcel the surface relation type should only take the values below or mixed etc.

3.2 The Prototype—Case Study in Greece

As mentioned before, the methodological steps are implemented using as basis a proposed model for Greece based on LADM. Different attributes are added to the GR_SpatialUnit class such as *HasTopoMap* (already a class of HC model, showing whether there is a topographic map attached together with the ownership declaration or not), *InsideMap* (whether the property is inside the city plan or not), etc.

According to ISO 19152 (2012), LA_Level and therefore, GR_Level is a collection of spatial units with a geometric or thematic coherence. This concept is important for organizing the spatial units. In this way, in relation to the principle of "*legal independence*" (Kaufmann and Steudler 1998) different groups of coherent spatial units can be created. For the proposed model, this structure allows for the flexible introduction of spatial data from different sources and accuracies, including utility networks, buildings and other 3D spatial units, such as mining claims, or construction works, etc.

The various types of spatial units are organized in levels using the class GR_Level. For this class there is an attribute type that describes level type of the spatial unit, which will include: archeological space, land parcels, marine parcels, panning zones, mines and SRPOs. The code list for these attributes can refer to GR_LevelContentType.

For Greece, the following levels are proposed: level 1 for archeological, level 2 for 2D parcel, level 3 for 3D parcel, level 4 for mines, level 5 for SPROs, level 6 for planning zones and level 7 for marine parcel. In the involved classes a constraint has been added to make this more explicit. For instance, GR_Mine has a constraint GR_Level.name = "level 4".

Taking for example the level referring to SRPOs. Special Real Property Objects considered an individual entity also in the existing model of the HC. This is due to the fact that they are properties built above or below other properties, usually found in Greek islands. Customary law applies in most Aegean islands creating complex RRRs, mixed up in multiple layers below or above the surface. Legal relations on those RRRs are presented through characteristic cases and examples of the complex 3D reality.

As SRPOs are already separate entities at the HC data model it is considered that a new level for them should be created (Fig. 5). RRRs are connected and affect each other, as well as connect parties and property units. Separate ground floor (e.g. katoi) and upper floor (e.g. anoi) residences have been traditionally under a system of horizontal property, evidently not complying with the Roman accession rule. The owner of the ground floor also owned the land parcel, while the owner of the upper floor owned the roof (and the air), having no land share. Under this special system of co-ownership, each floor's rights, even without land share, are separate, transferable and registrable. It is clear that there is no way to explicitly describe those relationships in two dimensions. The integration of these legally defined spaces to a 3D cadastral system should leave no doubt about their 3D registration.

What makes the development of this model unique is that it supports a wide range of spatial units, each of them having different requirements. The model also includes the content of various code lists, which are an important aspect of standardization and unique for each country. Code lists are used to describe more open and flexible enumeration values and are useful for expressing a long and potentially extensible, list of potential values.

Because of the special characteristics and complex structure of the proposed model, it was a challenge to use it as case study to test the prototype methodology. At the beginning, the model was implemented in Enterprise Architect software, described by UML. EA apart from the modeling part also supports generation and reverse engineering of source code; the automated conversion from the UML class diagrams to the technical model in Data Definition Language (DDL) and then creation of the SQL statements and generation of the database schema.

Although this process is automated, some limitations appear. The most important is that most of the constraints set at the UML diagram are lost through this conversion and because the number of inter-relationships between the classes of the proposed model is many, it is difficult to directly translate them in SQL. Moreover, the code lists are also a key challenge, as the enumeration list derived from the automated conversion cannot be extended.

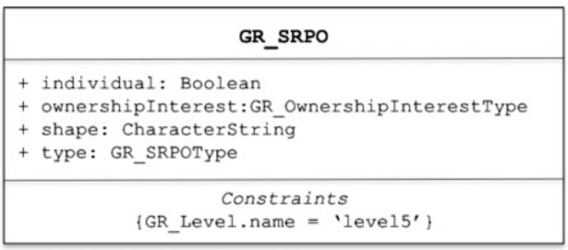


Fig. 5 GR_SRPO class of the proposed model; constraint added (Kalogianni 2015)

Therefore, the result needs manual interpretation. At that point the Swiss standard INTERLIS was considered a challenging solution to get computer processable model description and transfer LADM classes via XML (Germann et al. 2015).

INTERLIS was used as intermediate to derive the technical model from the conceptual. As a first step, the XMI (XML metadata format) was exported from EA describing the proposed model and imported in INTERLIS UMLeditor tool. It was expected that the model would be described in INTERLIS language and also a representation in diagrams would be available.

However, the XMI versions of EA and INTERLIS are not (yet) compatible, as INTERLIS uses Rational Rose XMI and EA exports to XMI 1.1. and XMI 2.1. Figure 6 depicts the technical problem presented during the development of the prototype.

Therefore, 3D MLAS model was translated manually into INTERLIS language and imported into INTERLIS compiler to quality check the INTERLIS model. Then the database schema from INTERLIS is derived. Below, is presented the GR_BAUnit class described in INTERLIS language.

More INTERLIS described classes are presented in the Appendix I.

```
CLASS GR_BAUnit EXTENDS LADM.Administrative.LA_BAUnit =
name (EXTENDED): CharacterString;
type (EXTENDED): MANDATORY LADM.Administrative.LA_BAUnitType;
KAEK : CharacterString;
horizontalPropertyID : int;
verticalPropertyID : int;
extArchiveID : Oid;
END GR_BAUnit;
```

The next step was to import sample data into the model and test its efficiency with real data. It is interesting to see whether some constraints are being violated, how much time a spatial query needs to be interpreted, etc.

The most important steps during the INTERLIS implementation were the formulation of code lists (avoiding the creation of enumeration types, which are fixed values and not extensible), the expression of constraints (as presents at the code fragments below), the aggregations between the classes and the support of 3D geometry for the representation of spatial units. Additionally, the description of multiple ISO standards that LADM uses as basis, such as ISO19107, ISO19111, ISO19156, and so on, were already described in INTERLIS and ready to use, from the Swiss Land Management.

In particular, there is a stack of INTERLIS models described from the Swiss Land Management: the ISO191xx base and also the datatypes that are used by LADM are specified (*LADM_Base*); then, the 3D MLAS model (*LADM_GR*) was described and each layer uses the model layer illustrated at the following figure, starting from the base to the top. This step facilitates the progress as most of the data types needed for the description were already defined (Fig. 7).

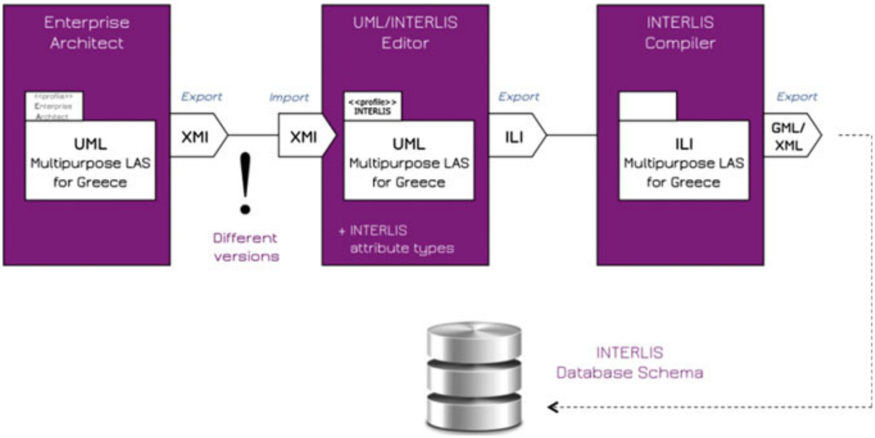
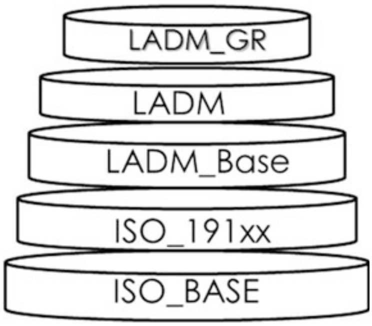


Fig. 6 Technical steps and problems through the development of the prototype

Fig. 7 Stack of INTERLIS models used to describe LADM country profile for Greece

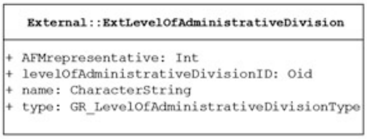


A sample INTERLIS code fragment from each of the model layers is displayed below. In particular, a part of ISO19107 and a part of LADM_Base in INTERLIS are presenting below. Additionally, an example of an external class (*ExtLevelOfAdministrativeDivision*) of the proposed model described both in UML and INTERLIS is presented.

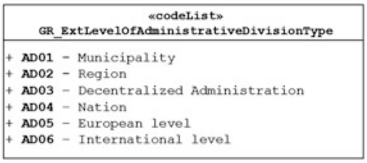
The relatively recent integration of Greek municipalities under the new (Kallikratis Plan) organizational schema does not remove the need for a separate management of the (former) sub-municipalities and thereby a more flexible land administration is provided. Because of the multiple levels of administrative division that have been created, the list of values is dynamic and there is great likelihood that additional values will be added, code lists are selected instead of enumeration types.

Please note the *IMPORTS* statement to include a model layer below.

```
!!-----------------------------------------------------
!!
!! ISO 19107 Geographic Information - Spatial Schema

   ....

   DOMAIN

   ....

      STRUCTURE GM_Point =
         geometry: Coord3D;
      END GM_Point;

      STRUCTURE GM_MultiCurve =
         geometry: LIST {1..*} OF Curve3DListValue;
      END GM_MultiCurve;

      STRUCTURE GM_MultiSurface =
         geometry: LIST {1..*} OF Surface3DListValue;
      END GM_MultiSurface;

END ISO19107.
```




```
TOPIC External [Abstract] =

STRUCTURE ExtLevelOfAdministrativeDivision
    AFMrepresentative : Int;
    levelOfAdministrativeDivisionID : Oid;
    name : CharacterString;
    type : GR_LevelOfAdministrativeDivisionType;

END ExtLevelOfAdministrativeDivision;
```




```
GR_LevelOfAdministrativeDivisionType =
[Municipality, Region, Decentralized
Administration, Nationm European level,
International level]
```

```
!!-----------------------------------------------------
!!
!! ISO 19152 LADM modelled with INTERLIS 2

   ...

   IMPORTS UNQUALIFIED ISO_Base;
   IMPORTS UNQUALIFIED ISO19115;

   DOMAIN

      STRUCTURE VersionedObject =
         beginLifespanVersion: MANDATORY DateTime;
         endLifespanVersion: DateTime;
         quality: LIST {0 .. *} OF DQ_Element;
         source: LIST {0 .. *} OF CI_ResponsibleParty;
      !! MANDATORY CONSTRAINT
      !!    (endLifespanVersion(n-1) = startLifespanVersion(n));
      END VersionedObject;

      STRUCTURE Fraction =
         denominator: MANDATORY Integer;
         numerator: MANDATORY Integer;
         !! Functions()
         !! equals(Fraction): Boolean;
         !! real(): Real;
         !! invariant
         !! denominator > 0;
         !! numerator > 0;
         !! numerator <= denominator;
      END Fraction;

   ...

END LADM_Base.
```

Fig. 8 UML and INTERLIS description of the proposed model

Figure 8 depicts two classes of the Greek 3D MLAS and a code list described both in UML and INTERLIS. To make a code list class semantically more meaningful, an attribute indicating the parent of the code list, in case that it exists, was added, other-wise it was considered as top-level code list. This means that if a code list has been introduced for the proposed model and has not been previously defined at the LADM description in INTERLIS, it is considered as a top level code list. Also, the code list is versioned, which means that it could be used to update the description of a specific code list value. On the other hand, if the code list has already been defined, the parent to which it is associated it is also defined.

An example with LA_PartyRoleType is mentioned below.

```
CLASS LA_PartyRoleType EXTENDS VersionedObject =
partyRoleTypeCode_ID: MANDATORY Oid;
parentCode_ID: Oid referring to
LA_PartyRoleType.partyRoleTypeCode_ID;
description: CharacterString;
!! Possible code list values: surveyor, notary, other
END LA_PartyRoleType;
```

Of course this raises questions; for instance, can anyone who models create a top-level code-list? And if yes, then how communication between the different modelers can be achieved? However, such questions are out of the scope of this paper.

INTERLIS closed enumeration types can be extended, for instance, in most of the code lists described in UML there is the value “other” that can be further extended. However, this results in a new enumeration type; and the classes that use this type also need to be remodeled.

3.3 Problems and Strengths of the Prototype

The prototype is still on an ongoing process. So far, the conversion from the conceptual UML model to a physical database has been achieved. More is yet to come, as the database will be populated with real data that have been gathered in order to test the efficiency of the database, implement the necessary changes and finalize the model. The criteria for choosing the best candidate for the description of the physical part of the objects need further exploitation, as the technological developments are rapid.

Until now, some technical modeling difficulties have been addressed; e.g. the compatibility problem between UML and INTERLIS while some modeling obstacles need to be further faced.

4 Conclusions and Discussion

This paper describes the prototype development based on LADM, INTERLIS and a model proposed for Greece. Many technical design and implementation decisions have been elaborated on during the conversion of the conceptual model to database schema.

The conceptual model is a proposal covering a broader perspective than the one of the HC, including 2D and 3D objects and interests that are not registered to the HC. The various types of spatial units are organized in levels using the class GR_Level. The levels of spatial units include: archeological space, 2D and 3D land parcels, marine parcels, panning zones, mines and SRPOs.

By applying INTERLIS to the proposed model, we get directly implementable data models, which speed up the implementation of LADM model. INTERLIS was chosen among other tools as it allows formal description of constraints. For the proposed model there are many types of constraints that can be found, i.e. end date of unfinished construction must be equal to start date of a building, if there is a co-ownership in a parcel the sum of the RRR share should always be 1, (Sect. 3.2.). Also, automated quality control of the data is offered using INTERLIS compiler tool.

One of the most difficult steps towards the prototype was the formulation of the code lists, as they should be extended and semantically rich. They were given a unique identifier (e.g. PR07), which will facilitate the exchange of information. Additionally, an extra attribute was added to support hierarchy in code lists; it needs further identification as a next step.

Finally, INTERLIS supports 3D point/line and polygons. Although there are not special 3D-volumetric types at the moment (Germann et al. 2015), it is still considered appropriate for the development of this prototype as it provides the basic 3D geometry types which can be used as basis for the definition of more complex types. Therefore, the next step is to further improve the 3D volume types supported by introducing polyhedron and/or solid types.

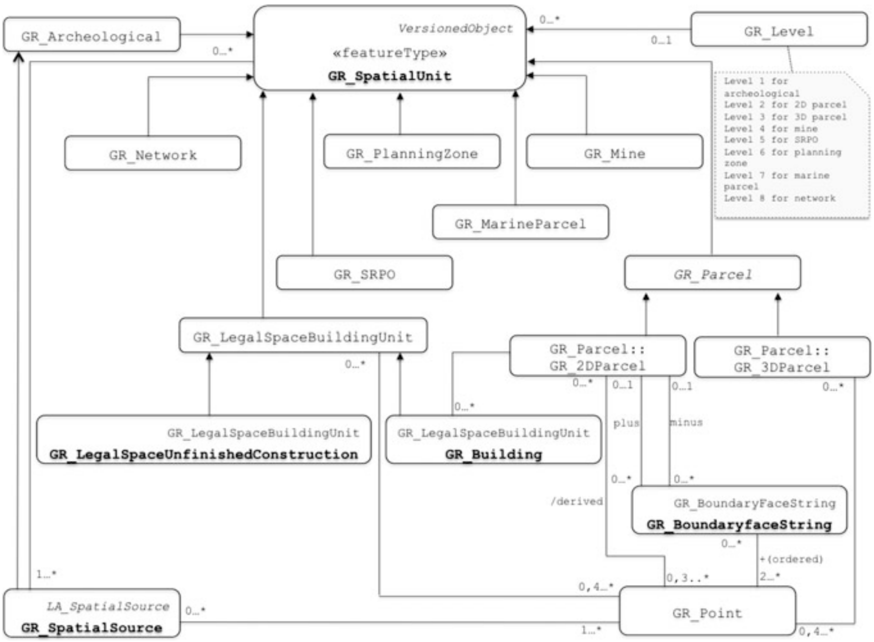
Further research aims to investigate the best candidate for the description of the physical objects and the implementation in 3D environment in order to investigate similarities and differences, as well as patterns between the physical and the legal reality.

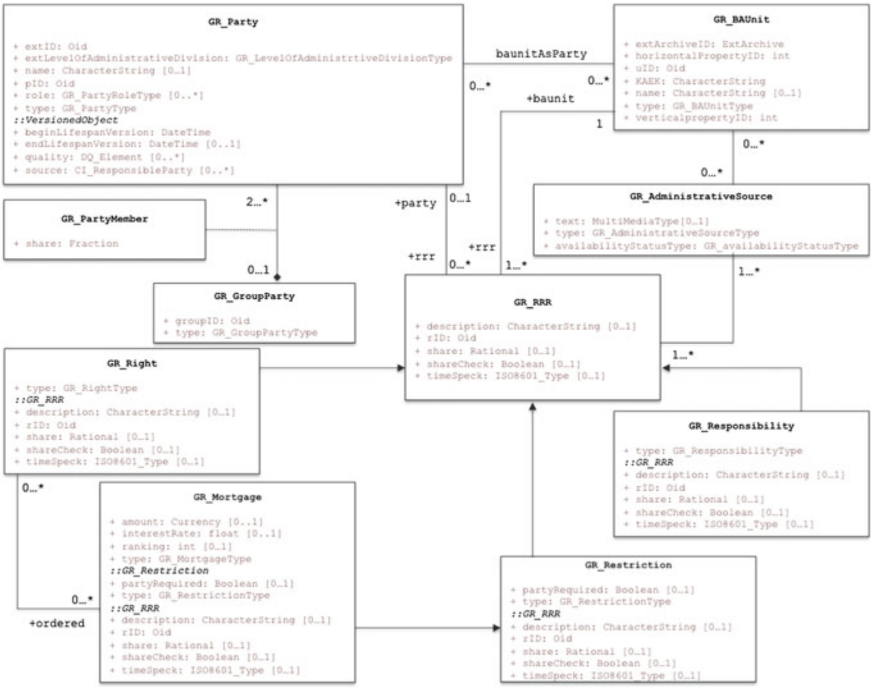
Appendix I—INTERLIS Implementation

```
!!------------------------------------------------------
!!
!! LADM_GR modeled with INTERLIS 2

   ....
   TOPIC Party(ABSTRACT) =

   DEPENDS ON  Spatial_Unit, Administrative, Surverying and
   Representation;

   DOMAIN
       GR_PartyType = (group,natural_person,nonnatural_person,
       basic_administrative_unit,Greek_public_state,
       foreign_state, European_Union,unknown);

       GR_PartyRoleType = (lawyer,bank,notary,citizen,
       institution, tax_office,insurance_organization,
       church,surveyor,metropolis,parish,court,
       courtof_appeal,high_court,state_council,
       legislative_authority,exproperiation_committee,
       ministry,local_authority,urban_planning_authority,
       general_secretary_of_the_region,to_be_filled);
```

```
        GR_GroupPartyType = (consortium,association,family,
        fraternity,guild,partnership,corporation,
        public_limited_company,private_limited_company,
        group_of_BAUnits,committee,other);

        GR_levelOfAdministrativeDivisionType =
       (municipality,region,nation,european_level,
        international_level,decentralized_administration);

       CLASS GR_Party EXTENDS LADM.Party.LA_Party =
           extLevelOfAdministrativeDivision :
           GR_LevelOfAdministrativeDivision;
           name (EXTENDED): CharacterString;
           role (EXTENDED): LADM.Party.LA_PartyRoleType;
       END GR_Party;

       CLASS GR_GroupParty EXTENDS LADM.Party.LA_GroupParty =
             type (EXTENDED): LADM.Party.LA_GroupPartyType
       END GR_GroupParty;


END Party;
```

Appendix II—Conceptual Mode





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