Joint ISO/TC211 and OGC Revision of the LADM: Valuation Information, Spatial Planning Information, SDG Land Indicators, Refined Survey Model, Links to BIM, Support of LA Processes, Technical Encodings, and Much More on Their Way!

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SUMMARY

ISO standards, which are actually being applied, are subject to periodic revision, typically in a 6 to 10-year cycle. A UN-GGIM Meeting of the Expert Group on Land Administration and Management was held on 14-15 March 2017, in Delft and the main conclusion was that the revision of LADM was indeed needed in order to provide better tools to improve tenure security and better land and property rights for all. It was also noted that land administration is a rather complex domain, and thus the revision will involve many stakeholders, namely: ISO, FIG, OGC, UN-Habitat, UN-GGIM, World bank, GLTN (Global Land Tool Network), IHO, RICS, etc..

Further goals of the revision include: providing reliable Land Administration Indicators for the Sustainable Development Goals (SDG), developing standard(s) supporting a Fit-for-Purpose approach, paying attention to implementations and tools (not just conceptual model), and inclusion of valuation information (which might help to define/support the Fit-for-Purpose approach). In order to prepare the LADM revision, two workshops were organized: 16-17 March 2017 (Delft) and 11-13 April 2018 (Zagreb), with experts involved in the development of the initial version of LADM and representatives of all the mentioned stakeholders. For the purpose of the revision, it is important to analyze and compare currently operational and proposed country profiles and their implementations of the first version of LADM, ISO 19152:2012.

This paper gives an overview of the status of developments and the related proposals.

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1. INTRODUCTION

The development of the Land Administration Domain Model (LADM) was an initiative of the International Federation of Surveyors (FIG), see (Lemmen, 2012). In the beginning of 2008, after six years of preparations, FIG submitted a proposal to develop an International Standard for the Land Administration (LA) domain, to the ISO/TC 211 committee on Geographic Information of the International Organization for Standardization. The proposal received a positive vote and a project team started to work on the development of the standard.

Within TC 211, many issues and comments have been discussed during several meetings, held with a project team composed of 21 delegates from 17 countries. After positive results of the voting on the so-called New Working Item Proposal (NWIP) in May 2008 and on the Committee Draft (CD) in October 2009, the Draft International Standard (DIS) received a affirmative vote in June 2011; the stage of International Standard in a first Edition was achieved in December 2012 (ISO, 2012). Each step of development process within ISO, includes reviews from the involved countries.

The LADM is a knowledge domain specific standard capturing the semantics of the Land Administration domain. It provides a shared ontology, defining a terminology for land administration. The LADM covers basic information related to components of land administration: including water and elements above and below the earth's surface, as well as people. Those components concern: party related data; data on Rights, Restrictions and Responsibilities (RRRs) and the basic administrative units where RRRs apply; data on spatial units and on surveying and topology/geometry. LADM also includes the Social Tenure Domain Model (STDM).

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In order to prepare the LADM revision, two workshops were organized: 16-17 March 2017 (Delft) and 11-13 April 2018 (Zagreb), with experts involved in the development of the initial version of LADM and representatives of all mentioned stakeholders. For the purpose of the revision, it is important to analyze and compare currently operational and proposed country profiles and their implementations of first version of LADM, ISO 19152:2012. FIG did submit a New Working Item Proposal to ISO on the development of LADM Edition II in May 2018. The proposal includes the following main scheduled LADM extensions:

1. Extended scope of conceptual model. This includes valuation, SDG LA indicators, Performance Index, linking physical objects, indoor models, support to marine spaces, spatial planning/zoning with legal implications, other legal spaces: mining, archaeology, utilities;
2. Improvement of current conceptual model. This includes formal semantics/ontology for LADM Code Lists; more explicit 3D+time profiles; an extended survey model and legal model;
3. Encodings/technical models. This includes further integration with BIM/IFC, GML, CityGML, LandXML, LandInfra, IndoorGML, RDF/linked data, GeoJSON, and:
4. Process models for: survey procedures, map updating, transactions – including blockchain.

This paper will further report in the initial stage of the revision process where ISO/TC211 and OGC cooperate. First, an overview of the current developments in relation to the LADM standard is given in Section 2 of this paper. Then, the requirements for the development of Edition II are presented in Section 3, followed by an overview of some main new functionalities in Section 4. It should be noted that these are proposals and initial developments of the second edition of the model. The conclusions are provided in the last Section.

2. OVERVIEW OF DEVELOPMENTS

LADM – and also the STDM, the Social Tenure Domain Model are currently under implementation in several countries see FIG (2017) and FIG (2018a).

LADM is applicable in relation to the implementation of relevant parts of the New Urban Agenda (UN, 2017), FAOs Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security (FAO, 2012) and the Continuum of Land Rights as from UN-Habitat (UN-Habitat, 2008, Teo and Lemmen, 2013). This fits of course very well into the context of implementation of the Sustainable Developments Goals.

The Fit-For-Purpose approach in Land Administration (FIG/World Bank, 2014; UN-Habitat/GLTN/Kadaster, 2016) has been developed in reaction to the challenges set by the overall Global Agenda for Sustainable Development. The Fit-For-Purpose approach argues for cost-effective, time-efficient, transparent, scalable and participatory land administration, including Participatory Surveying, Volunteered Land Administration and Crowdsourcing. The principle of the Fit for Purpose approach is that the spatial, legal and institutional frameworks for Land Administration are in balance in such a way that tenure security can be established and maintained in a timely and affordable way, always aiming at the local, regional or national needs. The introduction of the Fit for Purpose Land Administration can be considered a new way of thinking in achieving faster, cheaper and more appropriate land administration systems for the world. In order to assure an easy and adaptable interoperability layer with other stakeholders, the Fit-For-Purpose Guiding Principles recommend the data model chosen for the Fit-For-Purpose Land Administration system should be based on (ISO 19152:2012) LADM and the derived STDM.

During the last two LADM Workshops, (FIG, 2017 and FIG, 2018a) held in Delft, The Netherlands in 2017 (FIG, 2017) and in Zagreb, Croatia, 2018 (FIG, 2018a) the need for extensions of the scope of the LADM standard and improvement of the LADM was identified. The main outcomes of the workshops can be summarized as:

1. The New Working Item Proposal (NWIP), as submitted by FIG to the ISO Technical Committee on Geographic Information (ISO TC 211), provides an overview of needs and requirements discussed by international experts during LADM Workshops in Delft, in March 2017 and in Zagreb in April 2018. The New Working Item Proposal has been accepted by ISO TC 211 and there was a call for participants for the Stage 0 project on ISO 19152 LADM in September 2018.
2. ISO Stage 0 project started in May 2018 (during the 46th Plenary Meeting Week of TC 211 Copenhagen, Denmark), given the potential broad scope, including fiscal/valuation extension module, more explicit semantics of code list values, further modelling LADM's rights, restrictions, responsibilities (RRRs), further modelling of LADM's survey and spatial representation, functionality for monitoring SDG Indicators (aggregated values at different levels), 3D/4D Cadastre, inclusion of spatial planning/zoning with legal implications, functionality in LADM in support of Marine Cadastre (esp. coastal zones), more explicit relations with Building Information Modelling (BIM), new types of legal spaces: mining, archaeology, utilities. Then, there was a first meeting in November 2018 in Wuhan, China, during the 47th Plenary Meeting Week of TC 211[1] on the approach and contents of the LADM Edition II.
3. Collaboration with partners – see Section 1 of this paper, is crucial and mandatory during the revision.

3. REQUIREMENTS FOR LADM EDITION II

The first edition of LADM should be upwards compatible with future editions. Future editions may have an extended scope. LADM improvements and extensions are needed – as well as LADM workflow/ process models. This section is based on the New Working Item Proposal as submitted by FIG to ISO TC 211; see also Lemmen et al. (2018).

[1] https://committee.iso.org/sites/tc211/home/plenary-meeting/47th-plenary-meeting-china.html

3.1 Scope

A proposal to extend the scope of LADM with a valuation perspective is available (Çağdaş et al., 2016, Çağdaş et al., 2017). This proposal provides a data model that could be used to construct information systems for immovable property valuation (as basis for taxation). The proposal provides a common basis for governments to direct the development of local and national databases, as well as for the private sector to develop information technology products.

The Global Land Indicators Initiative, see UN Habitat/GLTN, 2017 and also UN ECOSOC and African Union, 2016, seeks to derive a list of globally comparable harmonized land indicators, using existing monitoring mechanisms and data collection methods as a foundation. Internationally agreed standards will be key alongside agreed global concepts and evidence-based approaches. There is need for a foundation of a Land Administration Performance Index – which is possible linked to existing global frameworks or initiatives.

Legal space and legal objects have its own geometry which is in many cases not (or not completely) aligned with physical space and physical objects. Legal space should be linked to physical objects – by IDs or re-use of descriptions of space. BIM/IFC and CityGML offer options in this respect. The users of the indoor spaces create a relationship with the space depending on the type of the building and the function of the spaces. Applying LADM allows assigning rights, restrictions, and responsibilities to indoor spaces, which indicates the accessible spaces for each type of user. An IndoorGML-LADM model is one example of linking physical and legal objects. A normative reference to IHO S121 (Marine Limits and Boundaries) based on the LADM principles needs to be included in ISO 19152.

Spatial planning/zoning with legal implications. In principle this is a matter of coding zones in code tables (based on the local situations). It further implies integration of spatial planning and land administration environment. Re-use of zones from spatial planning into restrictions to land rights should be possible. Other legal spaces are related to mining, archaeology, utilities (2D or 3D).

3.2 Improvements to be included in LADM II

For the domain of land administration, the localization issue extends from language names to the various organizations and institutions dealing with interests in land. Paasch et al. (2015) and Stubkjær et al. (2018) propose code lists as a mean of internationalization by which the classes of the LADM may be related to the jurisdiction concerned. The issue of code lists has been addressed by the OGC as well, namely in terms of the document 17-050r1 Code List Manifesto (Scarponcini, 2017). Metadata and tenure atlases are relevant in this context. Tenure atlases provide overview on tenure systems and the level of recognition. This may include areas without land markets and nature preservation etc.

There is a model for representation of legal space with a datatype allowing the representation of volumes that are not completely closed. More functionality is required for a complete partition of space; more explicit 3D+time profiles. An extended survey model and legal model is needed. This implies adjustments from field observations to the spatial database and the generation of quality labels. Encodings models concern the further detailed technical specification of LADM based on existing standards: BIM/IFC, GML, CityGML, LandXML, InfraGML, IndoorGML, RDF/linked data, GeoJSON. BIM is very important in order to establish a link between BIM and land administration in relation to spatial planning and lifecycles of constructions/ buildings. Open data is about Coding of Rights, Right holders, Spatial Unit Types, etc. See Informative Annex J of LADM (ISO, 2012) – W3C.

3.3 Workflows and process models

Cadastral map updating includes adjustments and transformations of field observations (collected at different moments in time and with different survey instruments or use of imagery from different sources) to the spatial database. Management of areas is needed – there may be more than one area to be maintained for the same spatial unit – the legal area and the accurate area as calculated in the cadastral GIS. Implementation of tolerances to manage the differences should be flexible and purpose related. Results of subdivisions of spatial units may need to be shared with other systems. This includes results of readjustments and land consolidation.

Blockchain technology in transaction processes could be very well applicable for transactions in land administration. Conversion of social tenure to legal tenure is a process that may require different levels (layers) with related attributes. The same is valid for geometric quality improvements of the cadastral map.

A new class representing processes may be defined: a specialization of the class representing sources – thereby creating a connection between the classes of workflow management module and LADM classes.

Processes can be organized on the basis of use of electronic signatures in case of applications and information requests with public and private keys and encryption/decryption. Provision of information to data collectors for initial data collection or maintenance is a specific but very important process (task management, logistics).

New approaches in Land Administration include Volunteered Land Administration and Crowdsourcing. It is possible that right holders and communities collect and maintain their own data with a certain level of professional support for quality insurance etc. Participatory surveying is possible with GPS. Conversion from social tenure to legal tenure may require professional support – but it is easy to make this process complex and complex to make it easy. The Publication of parties, related rights and spatial units also via global services (as may be Google, Virtual Earth and Open Street Map and many others).

There will be a need for considerably more integration across the various national data and information systems and platforms in order to leverage the most effective data and analysis for evidence-based policy formulation and decision making. Image-based acquisition of cadastral boundaries needs access to huge image libraries – including historical imagery – to support large-scale implementations.

4. PROPOSED NEW FUNCTIONALITY IN LADM EDITION II

In this section a number of initial proposals for new functionality is introduced. The following new parts are include here: Valuation Information Model (Subsection 4.1), Spatial Planning Information Model (Subsection 4.2), Refined Survey Model (Subsection 4.3), 3D Spatial Profiles (Subsection 4.4), IndoorGML-LADM Combination (Subsection 4.5), and Processes (Subsection 4.6).

4.1 Valuation Information Model

Classes in the Valuation Information Model Package (under development) get a prefix VM as from Valuation Model. The main classes of the Valuation Information Model Package are: (1) VM_ValuationUnit, (2) VM_ValuationUnitGroup, (3) VM_SpatialUnit, (4) VM_Building, (5) VM_CondominiumUnit, (6) VM_Valuation, (7) VM_MassAppraisal (8) VM_TransactionPrice, (9) VM_SalesStatistic, and (10) VM_ValuationSource, see Figure 1.

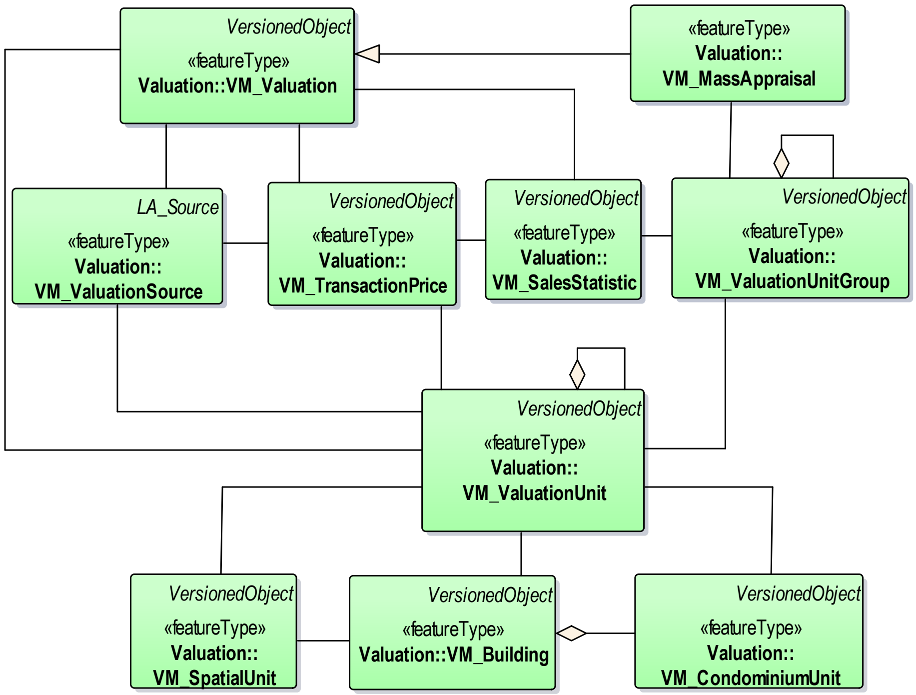

Figure 1 — Classes of Valuation Package

Valuation Units, as instances of VM_ValuationUnit, are the basic recording units of valuation registries, and realized by an aggregation relationship of VM_ValuationUnit onto itself, see Figure 1. The object of valuation may be (a) only land (e.g. cadastral parcel), (b) only improvements (e.g. buildings), (c) land and improvements together as land property, (d) land and improvements together as condominium property (McCluskey, 1999; Bird and Slack, 2002; Almy, 2014)

Valuation Units may be grouped as *valuation unit groups,* as instances of class VM_ValuationUnitGroup, and realized by an aggregation relationship of VM_ValuationUnitGroup onto itself, see Figure 1. A valuation unit group may be a grouping of other valuation unit groups. Examples of valuation units may be grouped according to zones (e.g. administrative divisions, market zones) that have similar environmental and economic characteristics, or functions of valuation units (e.g., commercial, residential, agricultural) that have similar physical characteristics.

Class VM_*SpatialUnit* represents for example cadastral parcels, as well as sub-parcels that are subjects to valuation activities. VM_SpatialUnit is a specialization class of LA_SpatialUnit.

Building represent physical spaces of buildings, building parts, other constructions, and their characteristics in valuation activities. A building may be considered as complementary parts of parcels (VM_SpatialUnit), but may be valued separately from the parcels on which they are located. This class coincides with the physical space of a building. A condominium building contains condominium units established according to condominium schemes. This class is adopted from the OGCs LandInfra standard (OGC, 2016). A condominium building consists of (i) condominium units (e.g. apartments, shops); (ii) accessory parts assigned for exclusive use (e.g. garages, storage areas); (iii) and joint facilities covering parcel, structural components (e.g. foundations, roofs), accession areas (e.g. entrance halls, spaces), and other remaining areas of buildings (e.g. staircases, heating rooms) (Kara et al., 2018).

Condominium units as instances of class VM_CondominiumUnit. A condominium unit is for the exclusive use of the individual condominium owner and shares a *condominium building.*

Class VM_Valuation, as counterparts of ExtValuation external class of LADM, is to specify output data produced within valuation processes, especially for property tax assessment. It concerns date of valuation, value type, valuation approach, and assessed value of valuation units.

Class *VM_Valuation* has a class as specification:

Mass appraisal, as instances of class VM_MassAppraisal. Mass valuation is a process of valuing a group of valuation units using standardized procedures at a given date. Class VM_MassAppraisal describes mathematical models, mass appraisal analysis types (e.g., multiple regression analysis), and the sample size of the analysis.

Transaction prices as instances of class VM_TransactionPrice. Class VM_TransactionPrice characterizes the information content of transaction contractor declarations, including the date of contract or declaration, transaction price, date and type of transaction (e.g., sale, heritage, forced sale, and rent prices).

VM_SalesStatistic, with sales statistics as instances. It represents sales statistics produced through the analysis of transaction prices. VM_TransactionPrice and VM_SalesStatistic serve valuation activities for different requirements, e.g. estimating property values for property taxation, expropriations, and monitoring price trends.

Valuation source as instances of class VM_ValuationSource. In principle, property valuation is based on a valuation source, as instances from class LA_ValuationSource.

4.2 Spatial Planning Information Model

It is common that countries to manage land tenure in a separate mechanism than spatial planning (Enemark 2004). International Federation of Surveyors (FIG) considers spatial plans are closely related with the cadastre as it may involve consultation and mediation processes in developing a new land use plan (FIG 1995). Extension of the standard is needed in developing an effective way to relate land tenure and spatial planning information. Standardization and harmonization of spatial planning information have been performed in Europeans countries through initiatives from each country, or a European wide, such as INSPIRE and multinational project, such as Plan4All (INSPIRE 2014, Murgante 2011, and Cerba et al. 2010). The standardization of spatial planning information in these initiatives mostly covered multiple layers spatial themes (e.g., land cover, land use, utilities, and government services, production and industrial facilities, agricultural and aquaculture facilities, regulation zones and reporting unit, and natural risk zones). Based on these ealier standardization efforts, the Valuation Information Model Package is now being development. The classes in this Package get a prefix SP as from Spatial Planning.

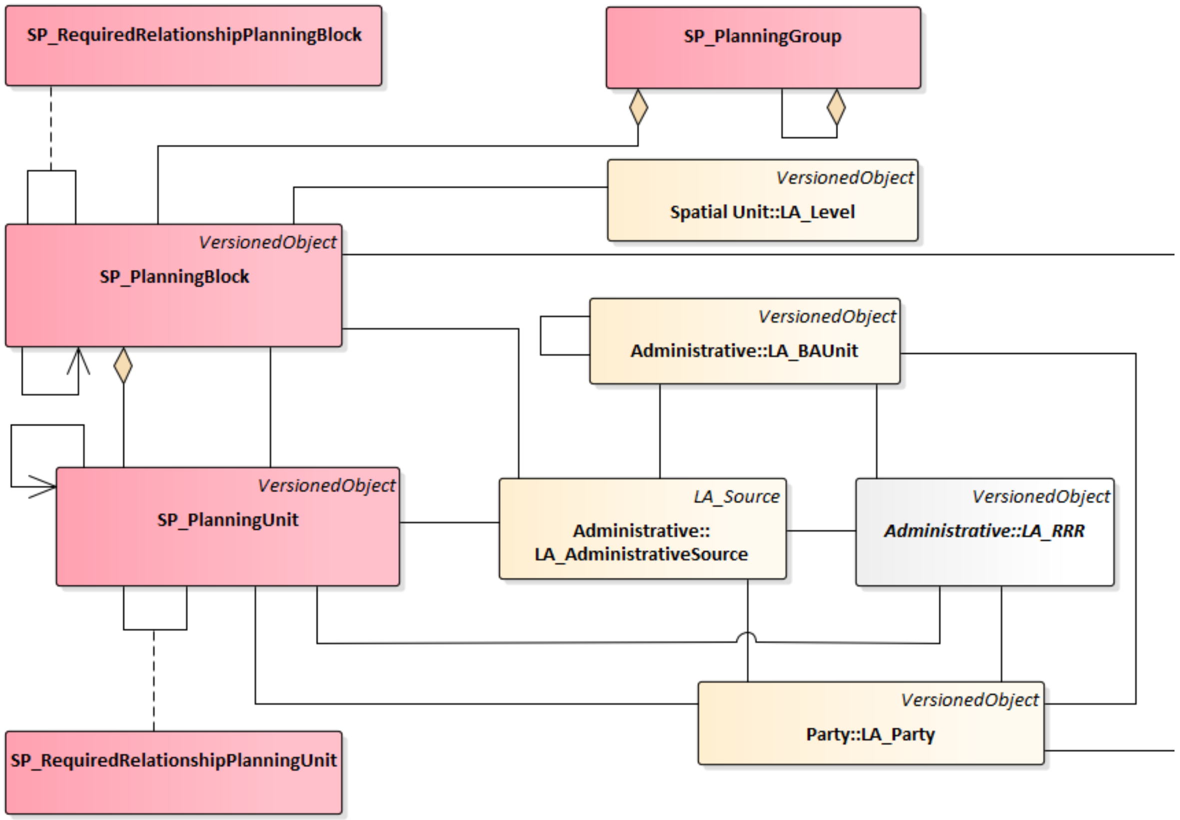

Figure 2 — Classes of Spatial Planning Packages and its relation to LA Party

The spatial planning information package consisting six classes: SP_PlanningBlock, SP_PlanningUnit, SP_PlanningGroup, SP_RequiredRelationshipPlanningBlock, and SP_ RequiredRelationshipPlanningUnit. This package also introduces an interfaceObject class in

LA_SubBAUnit to accommodate sub-parcel division of RRRs from land administration and spatial planning processes. Authors re-use existing LA classes as much as possible to maximize the integration of spatial planning information into LADM (Fig 9). SP_PlanningBlock contains spatial plan resulted from spatial planning processes. SP_PlanningGroup class accommodates aggregation and hierarchy of spatial planning from all levels of spatial planning, namely national plan, provincial plan, and city/municipality plan. In reality, SP_PlanningBlock is represented by a spatial plan map while SP_PlanningUnit is referring to zoning map (Fig. 9). Instance of SP_PlanningGroup is to accommodate hierarchy in spatial planning, such as (a) regional-wide (e.g., European Union), (b) Country-wide (e.g., Indonesia), (c) Island, (d) State or Province, (e) Municipality or City, and (f) Urban or Rural. The class SP_PlanningBlock has an optional association class: SP_RequiredRelationshipPlanningBlock while The class SP_PlanningUnit has an optional association class: SP_RequiredRelationshipPlanningUnit (See Figure 2). The required relationships classes facilitate declaration of explicit spatial relationships or criteria, such as to declare geometric quality (accuracy and precision) of a geometry of the spatial information classes or to declare topology relationship between planning blocks and land parcel.

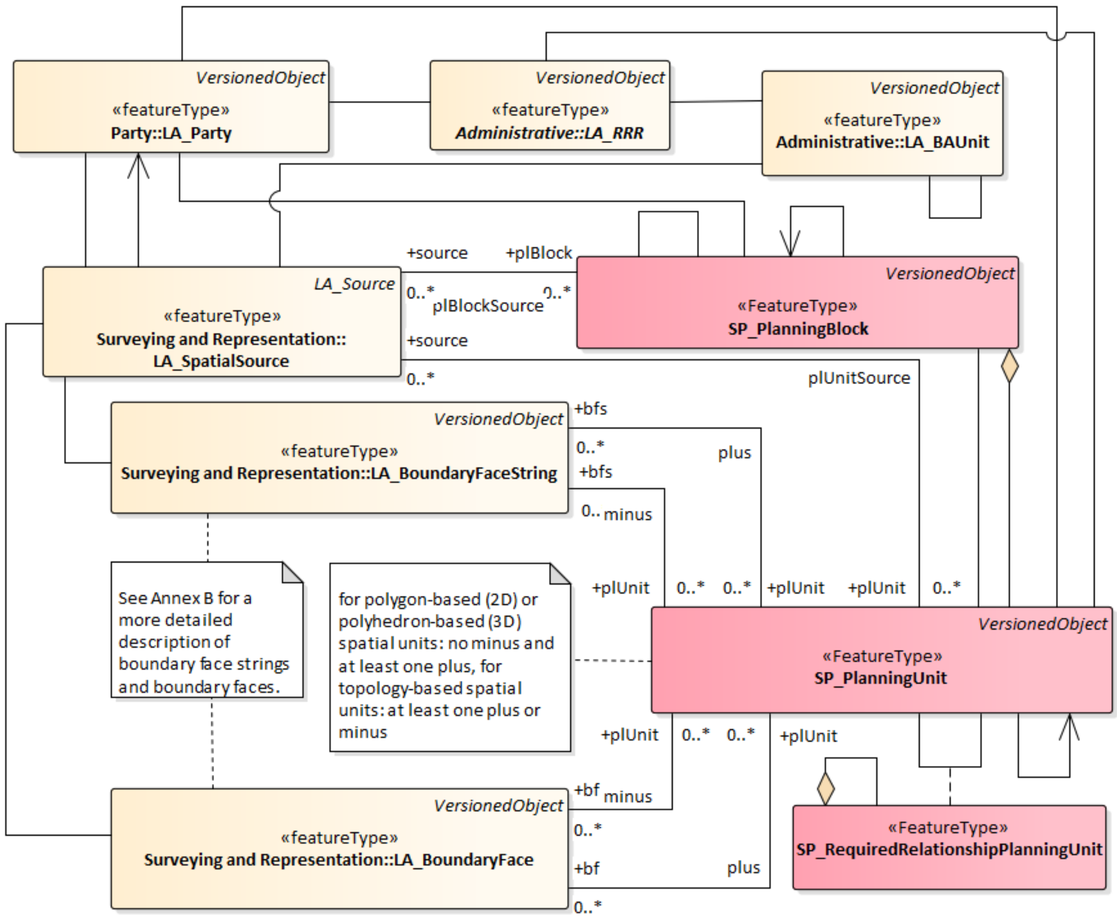

Figure 3 — Classes of Spatial Planning Unit Sub-Package

Both SP_PlanningBlock and SP_PlanningUnit reuse LA_BoundaryFace and LA_BoundaryFaceString geometry to represent sectoral policies integration through spatial planning processes (Fig 3). An instance of class LA_BoundaryFaceString accomodates a boundary face string of spatial planning area. LA_BoundaryFaceString is also associated to class LA_Point. Document related to geometry of spatial planning is contained in class LA_SpatialSource. In the case of a location by text, a boundary face string would not be defined by points. In case of a boundary face associated to a 3D planning unit, it can be described on one or more spatial sources; see **Fejl! Henvisningskilde ikke fundet. Fejl! Henvisningskilde ikke fundet.**. To accomodate multidimensional spatial planning, an instance of class LA_BoundaryFace is a boundary face and VersionedObject accomodate 4D (3D+time) representation for SP_PlanningUnit.

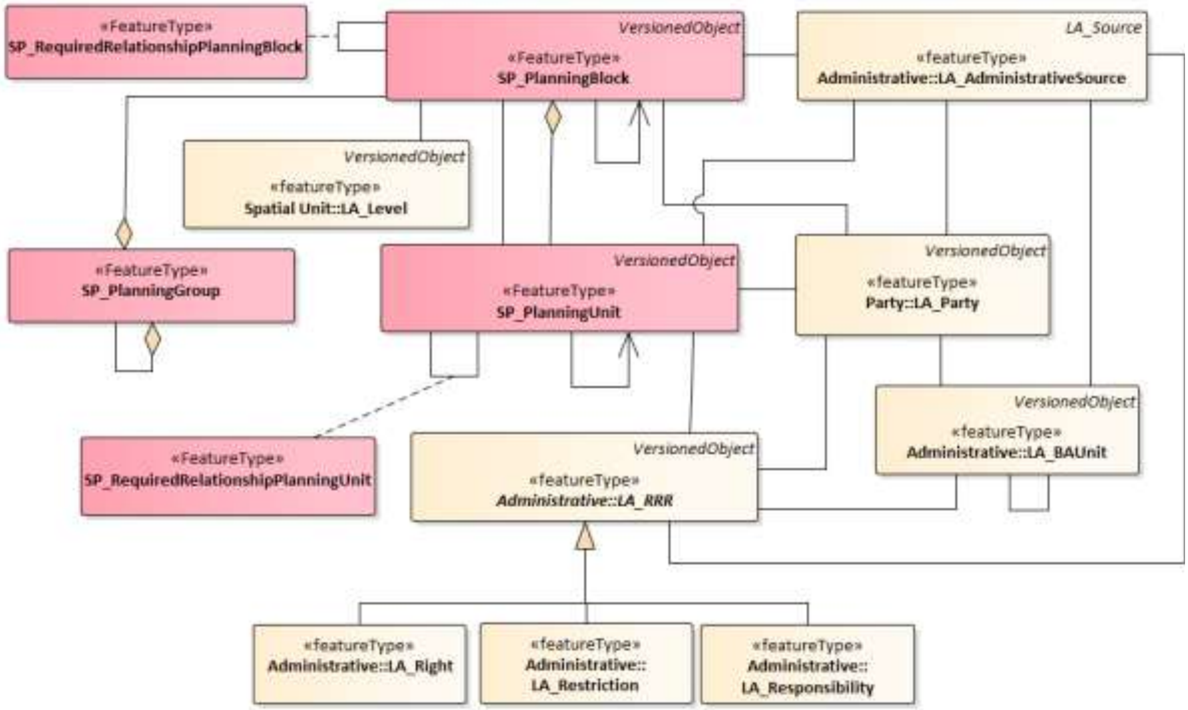

Figure 4 — Classes of Spatial Planning Administrative Sub-Package and its correlation with LA_RRR

The Spatial Planning Package accommodates RRRs derived from spatial planning into LA AdministrativeSource and LA_RRR. Administrative aspects of this package are basic classes of SP_PlanningUnit and SP_PlanningBlock (see Figure 4). LA_AdministrativeSource facilitates the foundation for rights, restrictions, and responsibilities derived from the spatial planning process. Class SP_RequiredRelationshipPlanningUnit allows for creating instances of relationships between SP_PlanningUnits. The RequiredRelationships classes are similar to BAUnit, which can be legal, temporal, or of spatial nature. An instance of the class SP_PlanningUnit registers a zoning unit which may contain RRRs derived from spatial planning processes. These classes are based on an administrative source; an instance from class SP_AdministrativeSource (see Figure 4). There is a unique combination between an instance of LA_Party, an instance of a subclass of LA_RRR, and an instance of SP_PlanningUnit to preserve the uniqueness of RRR for each SP_PlanningUnit. Both SP_PlanningUnit and SP_AdministrativeSource are related to LA_RRR representing the integration of RRR derived from spatial planning and land administration

4.3 Refined Survey Model

LADM refers to Observations and Measurement Standard (ISO, 2011), but in a very generic form therefore, a refined model for different survey techniques is required. In order to form a survey model an extended LA_SpatialSource class is suggested (Figure 5). New attributes have been introduced and complimentary Code Lists added, see Figure 6.

A new optional association class was created to connect LA_Party and LA_SpatialSource. The purpose of this association class is to denote the different roles of a survey executor that are not explicitly covered by role attribute in the LA_Party class. A new Code List for the surveyParty is also added.

Furthermore, a new association between the Administrative and the Spatial classes is suggested. The associations functions as an integrated source. 0 represents a case of a pure Administrative or Spatial source, whereas 1 illustrates a situation where a document contains both types of information.

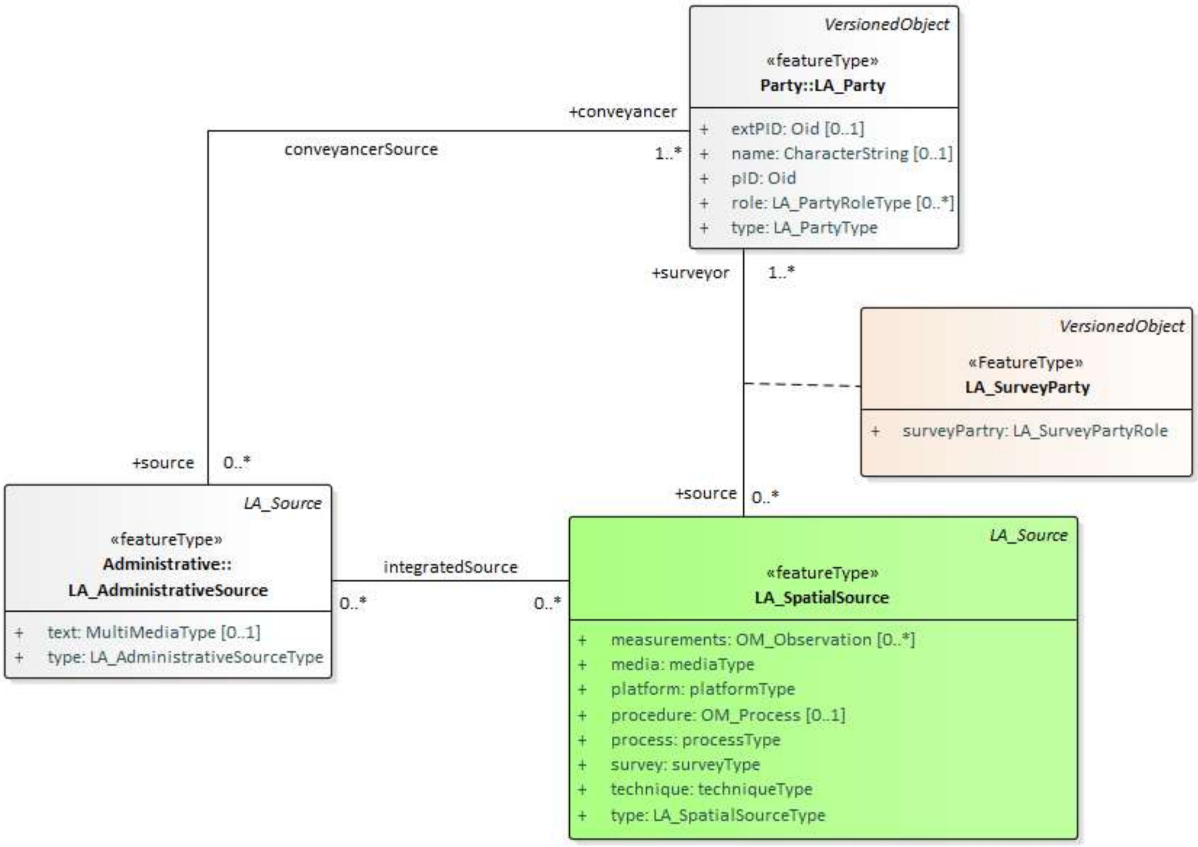

Figure 5 Extended LA_SpatialSource Class

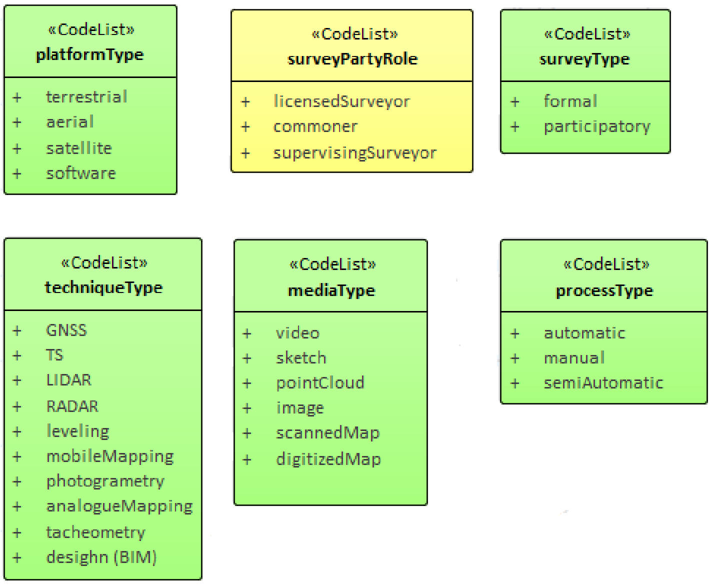

Figure 6 — Code List for extended LA_SpatialSource

4.4 3D Spatial Profiles

The level of geometric encoding as defined in ISO19152 provides a framework for categorization of spatial units recorded in a cadastre or other land administration organizations, ranging from "text based" spatial unit to the "topology based" encoding (both 2D and 3D). The initial classification of 3D spatial units was provided by Thompson et al. (2015) and forms the starting point for further investigation. The defined spatial units' categories (FIG, 2018b; Thompson et al., 2016) are listed below in an order of growing complexity (Kalogianni et al., 2018):

I. *2D spatial unit:* completely defined by the 2D location of points along its boundary. 2D spatial units are the most common in most jurisdictions and they actually implying 3D spatial units which have no explicitly defined bounded surfaces, as they actually define a prism, column of space above and below the land surface (Stoter and van Oosterom, 2006).

II. *3D spatial unit*: defined by a set of bounding faces, which are themselves defined by a set of 3D points and an interpretation. The following subcategories are defined for the 3D spatial unit:

- *Semi-open spatial unit:* defined by a 2D shape with one horizontal surface (upper or lower surface) – e.g. "*to the depth of …meters*". Semi-open spatial units are also common and very simple to store and to visualize in 2D.
- *Polygonal slice spatial unit*: defined by 2D shape with horizontal bounded surfaces (upper and lower surface), it is the most common form of closed 3D spatial unit. Individually, the units that lie in this category are easy to visualize and store. For both categories, semi-open spatial unit and polygonal slice spatial unit, the following subcategories depending on the nature of the surface definitions are defined:

- Above/below an elevation: the surface is defined by a horizontal flat plane at a height above/below a datum.
- Above/below a surface parallel to the local ground surface, and a defined distance above/below it.

- *Single-valued stepped spatial unit*: (**Fejl! Henvisningskilde ikke fundet.** 7C) defined by only horizontal and vertical boundaries, but non self-overlapping in z (i.e. at any location x, y there is only a single range of z values that belong to spatial units);
- *Multi-valued stepped spatial unit*: (**Fejl! Henvisningskilde ikke fundet. Fejl! Henvisningskilde ikke fundet.**) defined by a set of boundary faces, all of which are all either horizontal or vertical, without a restriction of the volume to being single valued in z. This allows volumes with "caves" or "tunnels" in the wall.;
- *General 3D spatial unit*: (**Fejl! Henvisningskilde ikke fundet. Fejl! Henvisningskilde ikke fundet.**) it is the "catch-all" category of spatial units, which fail to fit in one of the above categories. It is defined in part by boundaries other than horizontal and vertical and thus at its definition at least one boundary should be defined by one non-horizontal, or non-vertical face. This category may result to a further categorization of this class as the following boundaries lie in this category: 2-manifold, planar/curved boundaries, open/closed volume, single/multi- volume. It should be considered whether the sub-categories that will be created would be mutual exclusive, or would they be independent aspects and generate multiple categories form their possible combinations.
- *Building/construction format spatial unit*: (**Fejl! Henvisningskilde ikke fundet.** 7A) legally defined by the extents of an existing or planned structure that contains/will contain the unit. In the case that some jurisdictions decide not to record the geometry at this category, then it can be a 3D spatial unit with a "text-based" description, while for the rest that do describe the geometry, this category behaves like other 3D spatial units (usually polygon slice). The decision to record or not the geometry is purely local and could be applied to any type of spatial unit.
- *Any of these 3D Spatial Units can give rise to a Balance spatial unit:* It can be of any complexity as above but represents the remainder of a 2D spatial unit (i.e. prism) when all the 3D spatial units defined within it have been excised. The remainder (inner 3D region) could be of any complexity, but there are two variants of what this construct means:
  - The volume may be a primary interest excised from the 2D spatial unit (to avoid overlap);
  - The volume may define a secondary interest (e.g. lease, where overlap is allowed), therefore leaving the base spatial unit as a standard 2D spatial unit.

  In the case where 3D spatial units are modelled by a 3D geometry collection (polyhedra), within a 2D surface parcel, then the "Balance space unit" is the unit which comes as a result from prism - (minus) polyhedron. If the whole 3D domain is modelled as space partition using a 3D topology structure, then the "Balance space unit" will be a prism on the outside, with holes or caves made by the 3D geometries.

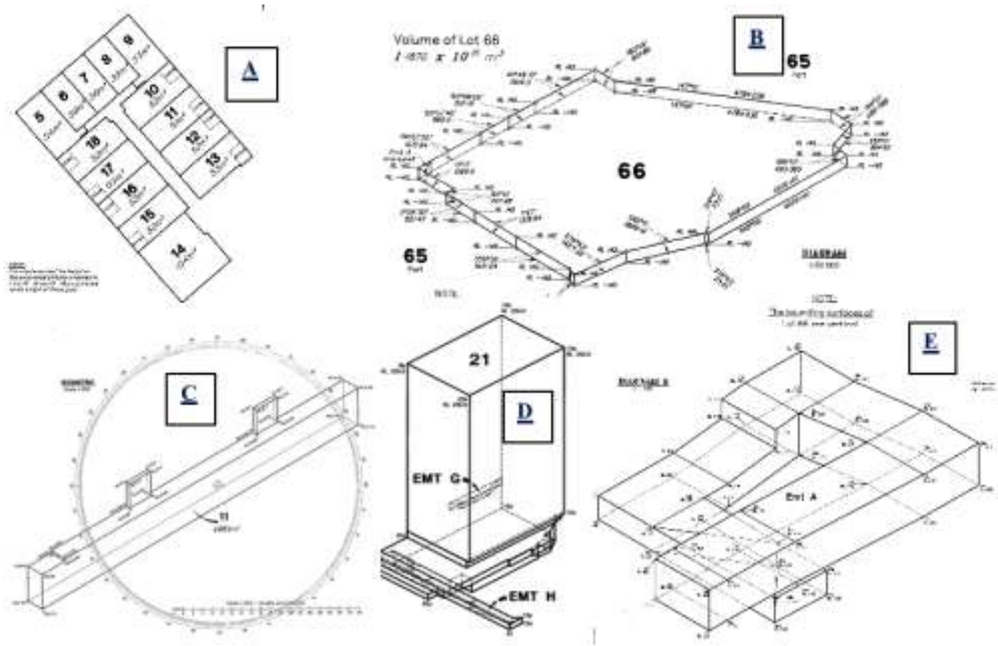

Figure 7 — Subcategories of spatial unit geometries: A. Building Format spatial units; B. Simple Slice; C. Single-valued stepped spatial unit; D. Multi-valued stepped slice ("EMT G" forms a "cave"); E. General 3D spatial unit (Kalogianni et al., 2018)

4.5 IndoorGML-LADM Combination

RRRs inside buildings are needed to support indoor navigation by managing the access and use of space for each party. The party of the indoor spaces establishes a relationship with the spaces according to the type of building and the function of the spaces. The party requires guidance in some buildings to reach their destination, and, thus, several navigation models have been developed for this purpose; however, these models do not distinguish between party types and how that could affect their accessibility rights. Therefore, the integration of LADM and IndoorGML allows assigning rights, restrictions, and responsibilities to each indoor space to determine the accessible spaces for each type of party. By representing the party types of the indoor spaces, LADM could establish a relationship between the indoor spaces and the party. As a result, the navigation process will be more convenient and more straightforward because the navigation route will avoid non-accessible spaces based on the rights of the party (Alattas et al., 2017). The combined use of IndoorGML and LADM covers a broad range of information classes: (indoor 3D) cell spaces, connectivity, spatial units/boundaries, (access/use) rights and restrictions, parties/persons/actors, and groups of them. The integration model of LADM and IndoorGML is part of a broad hierarchical framework of models for space subdivision based on RRRs of the party as shown in Figure 8.

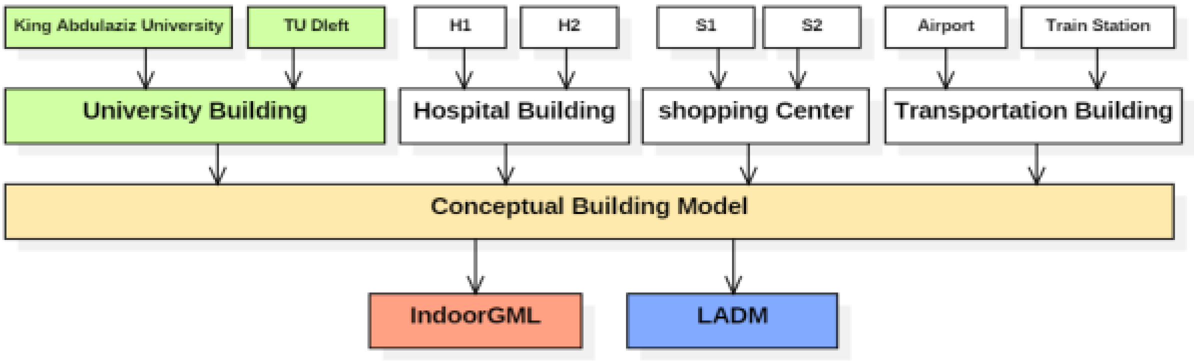

Figure 8 — Hierarchical framework of integration model (Alattas et al., 2018).

IndoorGML is an OGC standard that provides information of the indoor space and GML syntax for encoding geoinformation for the purpose of navigation (Alattas et al., 2018). IndoorGML determines a model to describe the geometry, topology and semantics of the indoor spaces that are utilized for the components of navigation routes. There are two categories based on the indoor spatial applications: 1) managing the building components and facilities, and 2) using the indoor space. The first category mainly focuses on the architecture elements of the building such as walls and roofs (discipline is called FM, facility management). The second category deals with the use and localization features of the indoor space, which leads to describing spaces such as rooms, corridors, and constraints elements such as doors. IndoorGML establishes a framework to determine static or mobile objects (agents) and provide spatial information services (navigation) by utilizing their positions in indoor space. IndoorGML represents the spatial character of the indoor spaces and provides information about their connectivity [Alattas et al., 2018b]. It has four different type of classes (GML, IndoorCore, IndoorNavi, and Not implemented) (Alattas et al., 2018). The combined UML model of IndoorGML and LADM is shown in Figure 9. Note the main links between these two models is via CellSpace (at the IndoorGML side) and LA_SpatialUnit/ LA_SpatialSource (at the LADM side).

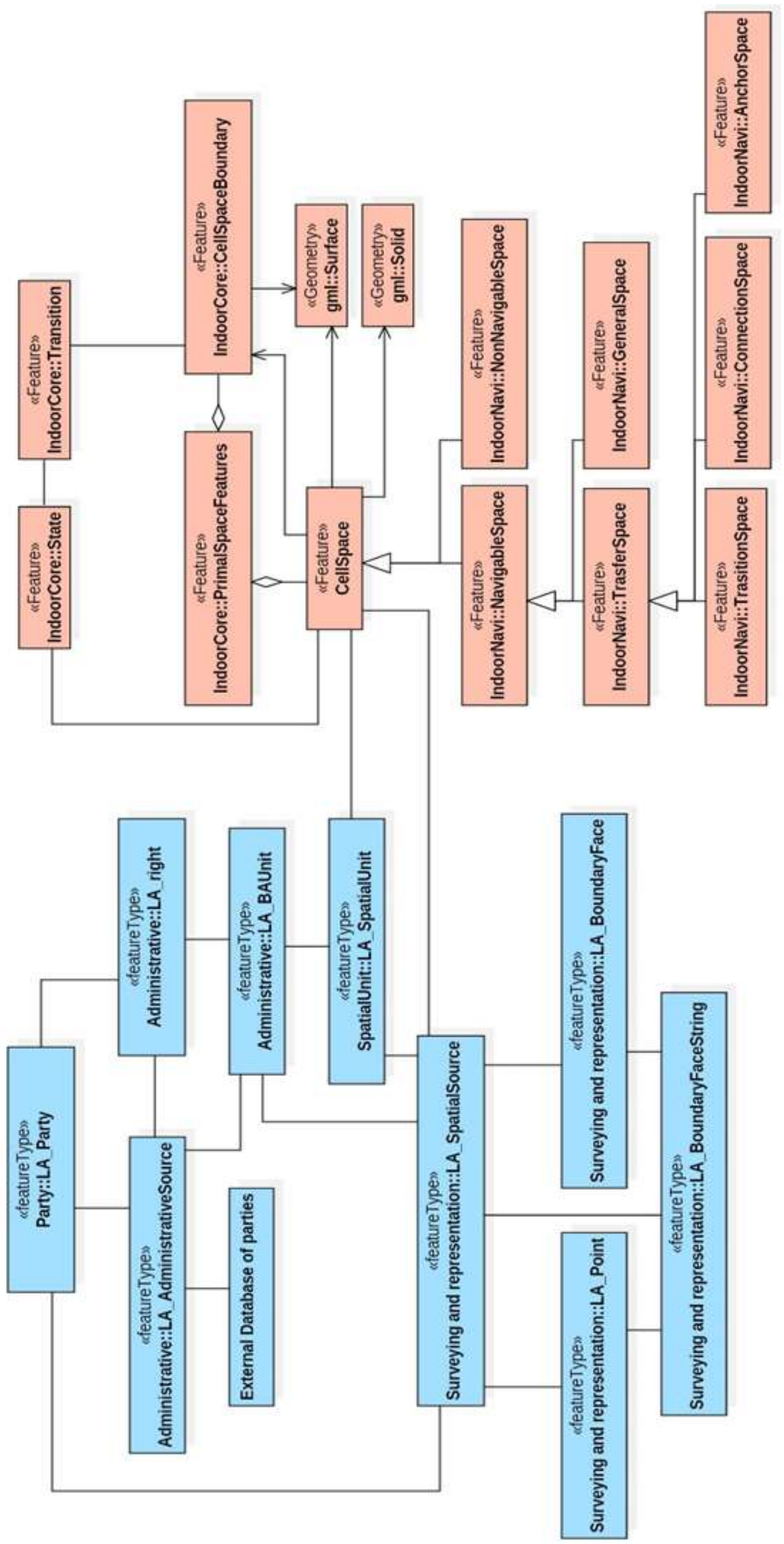

Figure 9 — UML model of LADM-IndoorGML combined model, the LADM classes are in blue and IndoorGML classes are in coral . IndoorGML

4.6 Processes

The LADM conceptual information model is completed by a model describing the various process. The LADM processes are organized per package and cover both data input and output. First, the processes related to the core LADM packages: Party, Administrative and Spatial Unit are described; second, the processes of the supplementary packages: Valuation and Spatial Planning are outlined.

Each process encompasses principle components and forms the legal or spatial correlation between them. Each element can be cross-connected to a corresponding LADM Class as demonstrated below.

- The ***interested party*** or the initiator of the process, might also be referred to as "stakeholder", that may be a person or an organization, such as: right holder, entrepreneur, municipality, government or an architect. This element of the process is denoted by the class ***LA_Party***.
- The ***executing party*** – licensed professionals or commoners who carry out the process, such as: surveyor, volunteer etc. The LADM class of this element is ***LA_Party***.
- The ***supervising*** or the inspectorial ***authority*** certified to approve, audit and/or execute the final step of a certain process. For example: land registrar, state surveyor, planning or tax authority which are represented as ***LA_Party*** as well.
- The ***input*** and the ***output*** of a process, may those be legal (deed/title) or spatial (map) products depend on the type of the process and can be represented by either ***LA_Source***, both spatial and administrative, or in some cases integrated sources, which are illustrated in the model via the association between the two subclasses of the LA_Source class. Some processes may include special units as their input/output and hence correspond to ***LA_SpatialUnit***.
- ***Format*** or a ***procedure*** of data exchange, submission or distribution required for the process. For instance, the use of DXF files for a cadastral map or request for registry form. These may be depicted by sources attributes such as ***mediaType***.
- ***Legal basis***: the laws, regulations and administrative guidelines relating to the process, may be presented in LADM by the ***LA_AdministratievSource***.
- The ***actions*** needed to be taken during the process, such as: selling, recording, surveying etcetera.
- ***Timeframe***, it is a common practice for a timeframe for each specific part of a particular processes to be set by law or in a case of lack of regulatory basis to be agreed upon by all the parties involved.
- ***Restrictions or constraints*** which are characteristic in a given process, may be formed as constrains in the LADM model

The general methodology for process modelling is of a hierarchical nature. The suggested framework consists of 4 steps – levels.

- Level 1 – Identification of all the actors/elements involved in a process according to the specified elements.
  Note: the actors and/or the elements might differ from country to country subject to enforced laws and accepted procedures.
- Level 2 – Identification of process phases, in other words groups or sub-processes relating to a certain topic and provision of generic description.
- Level 3 – Identification of basic activities.
- Level 4 – Building of a model.

The first two levels may be depicted by ***use case diagrams***, whereas Levels 3 and for can be presented via ***activity and/or sequence diagrams***.

5. CONCLUSION

A New Working Item Proposal for the development of a second Edition of the Land Administration Domain Model has been submitted by the FIG to the ISO Technical Committee 211 on Geographic Information.

This paper will be the first in a series to be published in the next years on the provision of overview of the developments and of the proposed functionality of the revised standard– in order to keep the professional community informed and involved.

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