The Road to a Standard Land Administration Domain Model, and Beyond…

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SUMMARY

The Land Administration Domain Model (LADM) is a Draft International Standard (ISO DIS 19152) and in January 2011 was distributed by the ISO central secretariat for a five month voting and commenting time interval. If everything goes as planned, ISO 19152 will be an International Standard (IS) by 2012. In this paper the road towards this standard is briefly described. An overview of the DIS and the changes during the last year of the LADM standardization process is given; most of the changes are textual and organizational improvements.

With the official status of the LADM as an International Standard approaching, the question arises: what's next? The answer is of course, implementation and use in practice. Already several *country profiles* have been created and other model usage is being conducted; e.g. the Land Parcel Identification Systems of the European Union and the Social Tenure Domain Model. It was noted in earlier publications that Land Administration is key in the information infrastructure and strongly related to other registrations. Within LADM these registrations are explicitly indicated as *external classes*, such as persons (*parties*), addresses, valuation, taxation, land use, coverage, physical utility networks, etc. Within the European Union, some of these domains are treated in INSPIRE, but certainly not all. Here lies an important role for FIG at a global scale (and with a relationship to ISO). Also, FIG could continue the work of ISO on Observations & Measurements (ISO 19156, under development) and make sure that this standard is refined for cadastral surveying needs.

The requirements from future land governance stem from improving registration of public restrictions, registration of public benefits, registration practices with regard to public land, registration of 'public goods' and its spatial extents and policy implications. In the past, there have been more publications on the anticipated developments of Land Administration, see (Van der Molen, 2003) and more recently (Bennett et al, 2010; Lemmens, 2010a; Lemmens, 2010b). The expected further requirements for the next decade are support of: mature information infrastructures to serve society; dynamic process models with updating/participation by actors; 3D, 4D and 5D that is, space, time and scale integrated in Land Administration; spatial design applications; new rights, restrictions and responsibilities; international semantic web-based seamless registration; monitoring applications and community driven cadastral mapping. LADM can bring support here from a modeling perspective.

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1. INTRODUCTION

The Land Administration Domain Model (LADM) has been published as a Draft International Standard (DIS) by the International Organization for Standardization (ISO, 2011), as ISO 19152. Participating Members of ISO/TC 211, Geographic Information, can comment on the draft and are in the position to vote on continuation of the development of LADM. Liaisons to ISO/TC 211, such as FIG, can also comment on the draft. The deadline for voting and comments is June 20th, 2011. The DIS has also been submitted to CEN member bodies for a parallel five months inquiry[1].

The development of LADM is an initiative of FIG. It is a comprehensive, extensive, formal process with a continuous review and a continuous, creative approach to find common denominators in land administration systems and included data sets. FIG submitted the LADM as a New Work Item Proposal to ISO/TC 211 in 2008. A four year development is normal and in this case possible because of preparations within FIG.

The Draft International Standard (DIS) covers basic information related to components of land administration (including water and elements above and below the earth surface). It includes agreements on data about administrative and spatial units, land rights in a broad sense and source documents (e.g. deeds or surveys). The rights may include real and personal, informal rights as well as indigenous, customary and informal rights. All types of restrictions and responsibilities can be represented. Overlapping claims to land may be included. The draft standard can be extended and adapted to local situations; in this way all *people land relationships* may be represented. This can be supportive in the development of software applications built on database technology.

LADM describes the data contents of land administration in general, based on a practical approach. The roots are in FIG's Cadastre 2014 (Kaufmann and Steudler, 1998). Implementation of LADM can be performed in a flexible way; the standard can be extended and adapted to local situations. External links to other data bases, e.g. addresses, are included. Legal implications that interfere with (national) land administration laws are outside the scope of the LADM.

[1] There is a close cooperation between ISO/TC211 and (European) CEN/TC287 Geographic Information. Via resolutions adopted by both organizations, it is agreed on how this cooperation is implemented. On 26 February 2009, in the Madrid meeting of CEN/TC287 after voting on the 'ISO19152 Draft Resolution 153 New Work Item Proposal Geographic Information – Land Administration Domain Model (LADM) - second vote' (CEN document number N 1304) it was decided to accept the LADM within CEN TC287.

LADM can be a basis for combining data from different Land Administration Systems. The Draft International Standard includes informative example cases with people and land relationships demonstrating the flexibility of the draft standard. Further, the relationships with the INSPIRE (Infrastructure for Spatial Information in the European Community, (INSPIRE, 2009)) Cadastral Parcels model and LPIS (Land Parcel Identification Systems – this is a part of the Integrated Administration and Control System established by the European Union Member states) are described in annexes. 3D Cadastres are covered in such a way that these seamlessly integrate with existing 2D registrations.

Those efforts resulted in the Draft International Standard for the Land Administration Domain. Standards are widely known and used in surveying and land administration. From a mathematical perspective in surveying, the "gap between cultures" has been bridged for a long time. Results of survey activities as co-ordinates, object identification, areas are based on mathematics as a standard "language". Nowadays data handling, using database technology and geographic information systems, often uses functionality based on standardized data types (as points, lines and polygons); spatial operators (as inside or overlap) and spatial index systems. Implementation of reference systems evolve from local (regional, national) to global. The LADM opens options now to bridge gaps between cultures where *people land relationships* are concerned, definitively not only in support of globalization, but also with a strong attention to bring support in the protection of land rights (tenure certainty) for all.

This paper gives an overview of the road followed towards this standard in chapter 2. The latest updates from the developments within ISO are presented. Chapter 3 briefly presents the Draft International Standard. In chapter 4 a series of initiatives of using of the LADM is described. In chapter 5 expected future requirements are discussed.

2. DEVELOPMENT OF THE LAND ADMINISTRATION DOMAIN MODEL

The LADM has been designed and validated in an *incremental approach*. Initial versions in different stages have been discussed during several FIG and other events; an overview is given here below. A version 1.0 of the LADM was presented at the FIG Congress in Munich in October 2006 (Lemmen and Van Oosterom, 2006). At the beginning of 2008 FIG submitted a New Work Item Proposal to ISO. A Draft International Standard is available now.

2.1 Historical overview

The idea to develop a domain model was born at the FIG Congress in Washington DC, USA in April 2002. The initial version 0.1 was presented in September 2002 at an OGC meeting, organised in Noordwijk, The Netherlands, and at a COST[2] Workshop in Delft, The Netherlands in November 2002 (Van Oosterom and Lemmen, 2002). This version was called the Core Cadastral Domain Model. A second draft version 0.2 was presented (after expert reviews) at a workshop on Cadastral Data Modeling at the International Institute for Geo-

[2] CO-ordination in the field of Scientific and Technical Research - European Co-operation in Science and Technology

Information Science and Earth Observation (ITC) in Enschede, The Netherlands in March 2003 (van Oosterom and Lemmen 2003) and during the FIG working week, Paris, April 2003 (Lemmen and Van Oosterom, 2003).

The draft version 0.3 of the model development (with multi-purpose cadastre, 3D extensions, refinements and with more authors as domain specialists), was presented at Digital Earth, September 2003 in Brno, Czech Republic (Lemmen et al, 2003) and at the EULIS Seminar on 'Land Information Systems and the Real Estate Industry', Lund, Sweden, April 2004. During an Expert Group Meeting on Secure Land Tenure, in Nairobi, Kenya, November 2004 it became clear that customary tenure should be included (Van der Molen and Lemmen, 2004). The Nairobi meeting provided input from developing countries, which was worked out in the version of the model presented during the Second Workshop on Standardization of the Cadastral Domain, held in the Aula of the University of Bamberg, Germany, 9-10 December 2004 (Van Oosterom et al, 2004). In the draft version 0.4 presented in Bamberg there was attention to the system boundary (scope) and some other suggestions for further improvement were included in the conclusions.

The draft version 0.5 was presented at the FIG Working Week in Cairo, April 2005 (Lemmen et al, 2005). This version was mainly improved on the legal, administrative side of the model (based on the Bamberg workshop) and the model was made 100% compliant with the OGC and ISO/TC 211 standards. The LADM included reflection on the Arab world cadastral registration at the FIG meeting in Jordan, September 2005. Draft version 0.6 was presented at the UN-HABITAT expert group meeting in Moscow, October 2005 (Van Oosterom and Lemmen, 2006), and the FIG regional conference in Accra, Ghana, March 2006, including the third LADM workshop (Augustinus et al, 2006). The version 0.5 of the model had been submitted to ISO/TC211 and the written, all very valid comments have been addressed in the version 0.6. The received comments were related to including a class Building in the model, to better explain the relationship between rights and restrictions (often 'the positive and negative side of the same coin'), and to better explain the role of PartOfParcel (yet non separated area), and a remark on the need of not only standardizing the model but also possible information services. A version was presented in a scientific journal and it was decided to present the whole model, instead of the increments only, because of reasons related to completeness and readability (Van Oosterom et al, 2006a).

Finally, the version 1.0 of the LADM was presented at the FIG Congress in Munich in October 2006 under the name of 'version 1.0 of the FIG Core Cadastral Domain Model' (Lemmen and Van Oosterom, 2006).

2.2 Towards an International Standard for the Land Administration Domain.

At the FIG conference in Munich in October 2006 many cases and examples were worked through, including the initial filling of several code lists, which were until then only mentioned but not described with content. This document became the input for the ISO standardisation process (ISO/TC 211, 2008), which was subsequently reported in (Lemmen et al, 2009a).

Existing standards have been re-used, e.g. the ISO 19100 series or ISO 19156, Geographic information – Observations and Measurements, which is under development in ISO/TC 211. After the LADM New Working Item Proposal and the LADM Committee Draft, the LADM Draft International Standard is available now for comments and voting.

3. THE DRAFT INTERNATIONAL STANDARD (DIS)

During the last year, 2010, several comments from individual editorial committee members operating within TC 211 and also from member bodies of TC 211 have been processed. This resulted in the following updates:

- subpackages Surveying and Spatial Representation integrated and offering source points, lines, and surfaces,
- constraints around RRR improved (to control proper grouping),
- all associations now listed in text (and not only in UML diagram),
- old annex with feature and attribute catalogue integrated with clause 6 in main text,
- changes propagated from ISO 19156 Observations and Measurements (O&M) to LADM,
- geometry now either explicit in spatial representation or derived via associations to spatial source,
- new instance level objects diagram examples added to cover all LADM classes and cross referenced from main text (and better reflect informal RRRs), and
- several small corrections made in the UML diagrams (data types, multiplicity…).

Those updates and changes are presented here below in the context of a description of the Draft International Standard as it is available for voting by TC 211 members in June 2011. All figures are UML 2.1 diagrams. To differentiate LADM classes from other classes of ISO 19100 standards, their names are given LA_ as a prefix.

3.1 Packages of the LADM in the Draft International Standard

LADM, as a product, is a conceptual schema. LADM is organized into three packages, and one subpackage. (Sub)packages facilitate the maintenance of different data sets by different organizations, e.g. Land Registry or Cadastre (each with their own responsibilities in data maintenance), operating at national, regional or local level.

The three packages are: Party Package, Administrative Package and Spatial Unit Package. The Surveying and Spatial Representation Subpackage is one subpackage of the Spatial Unit package. In earlier versions those were two subpackages (one Surveying Subpackage and one Spatial Representation Package).

The core LADM is based on four basic classes (see Figure 1):
1) Class LA_Party. Instances of this class are *parties,*
2) Class LA_RRR. Instances of subclasses of LA_RRR are *rights*, *restrictions* or

responsibilities,

3) Class LA_BAUnit. Instances of this class are *basic administrative units*.
4) Class LA_SpatialUnit. Instances of this class are *spatial units*.

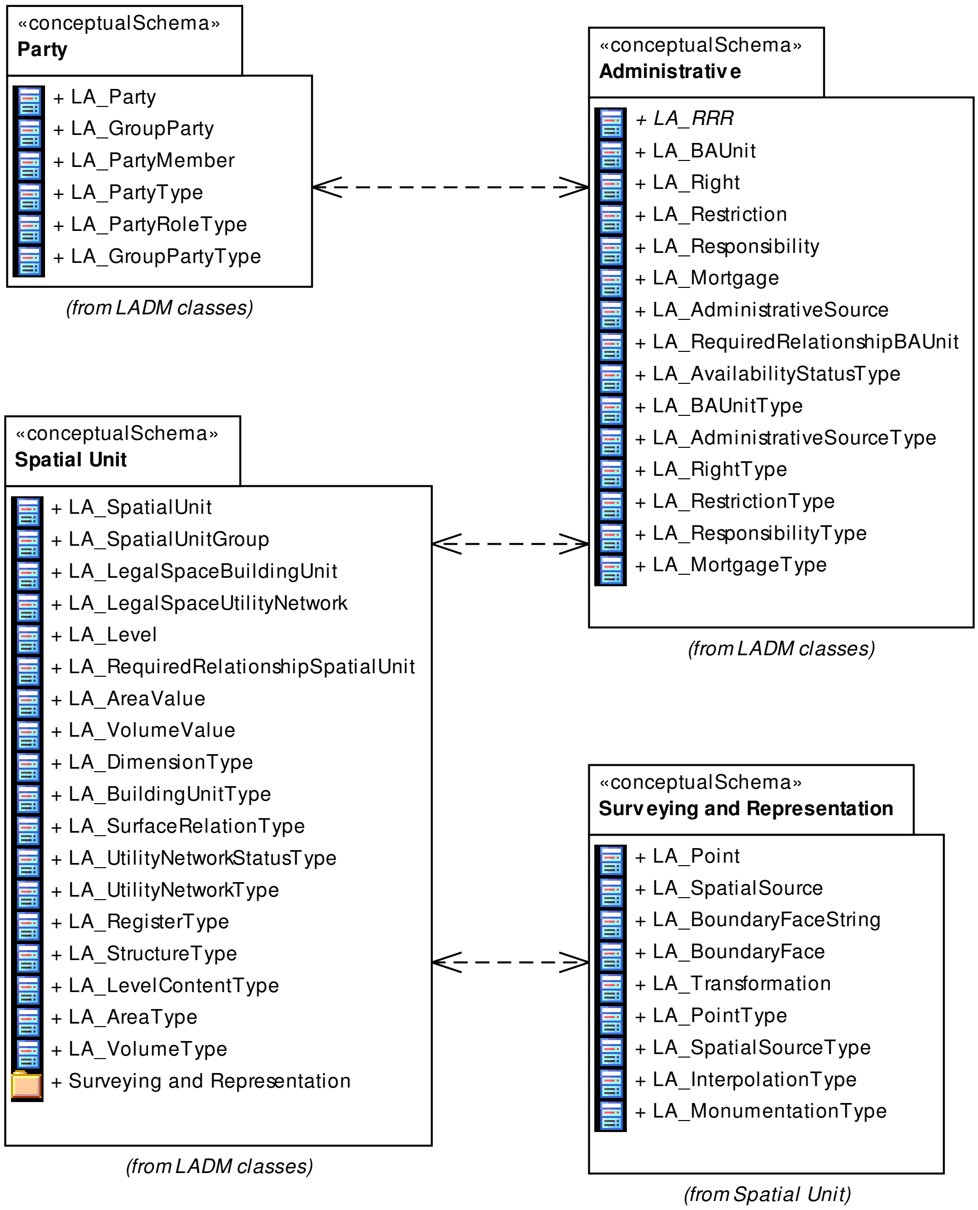

Figure 1 Basic classes of LADM

3.2 Party Package

The main class of the Party Package is the class LA_Party (with party as an instance). A party is a person or organisation that plays a role in a rights transaction. A juridical person may be: a company, a municipality, the state, a tribe, a farmer cooperation, or a church community (with each juridical person represented by a delegate: a director, chief, CEO, etc.). LA_Party has a specialization: LA_GroupParty. A group party is any number of parties, forming together a distinct entity, with each party registered or recorded. Between LA_Party and LA_GroupParty there is an optional association class: LA_PartyMember. A party member is party registered and identified as a constituent of a group party. See Figure 2.

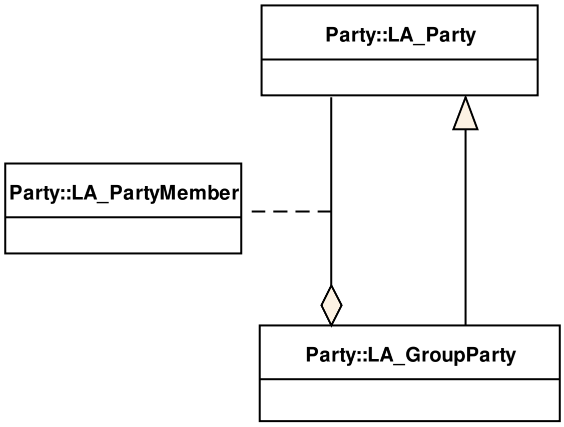

Figure 2 Classes of Party Package

3.3 Administrative Package

The main classes of the Administrative Package are basic classes LA_RRR and LA_BAUnit. See Figure 3. LA_RRR has three classes as specializations:

- LA_Right, this is an action, activity or class of actions that a system participant may perform on or using an associated resource. Rights are primarily in the domain of private or customary law. Ownership rights are generally based on (national) legislation, and code lists in LADM are in support of this, code tables are available for all "type attributes".
- LA_Restriction, this is a formal or informal entitlement to refrain from doing something. Restrictions usually remain valid when the right to the land is transferred. A *mortgage* (LA_Mortgage), is a special restriction of the ownership right. It concerns the conveyance of a property by a debtor to a creditor, as a security for a financial loan, with the condition that the property is returned, when the loan is paid off.
- LA_Responsibility, this is a formal or informal obligation to do something.

Instances of class LA_BAUnit are basic *administrative units* (abbreviated as *baunits*). Baunits are administrative entities consisting of zero or more spatial units against which (one or more) unique and homogeneous rights (e.g. ownership right or land use right), responsibilities or restrictions are associated to the whole entity, as included in a Land Administration System. Note: by unique is meant that a right, or restriction, or responsibility is held by one, or several parties (e.g. owners or users) for the whole basic administrative unit. The class LA_BAUnit contains a constraint expressing that the sum of shares in a subclass of RRR must be equal to 1. This means parties can hold a share in a right, restriction or responsibility. A special attribute indicates whether this constraint is valid or not, as in some cases this constraint is meaningless. By homogeneous is meant that a right, or restriction, or responsibility (e.g. ownership, use, social tenure, lease, or easement) affects the whole basic administrative unit. For a restriction zero parties are possible.

In principle, all rights, restrictions and responsibilities are based on an administrative source. Class LA_Required-RelationshipBAUnit allows creating instances of relationships between baunits. It allows maintaining explicit relationships between ba units in the absence of spatial units to describe the baunits, or in the presence of inaccurate geometry of spatial units to generate reliable implicit spatial relationships; e.g. in case of 'map conversion' from a less accurate to very accurate cadastral map.

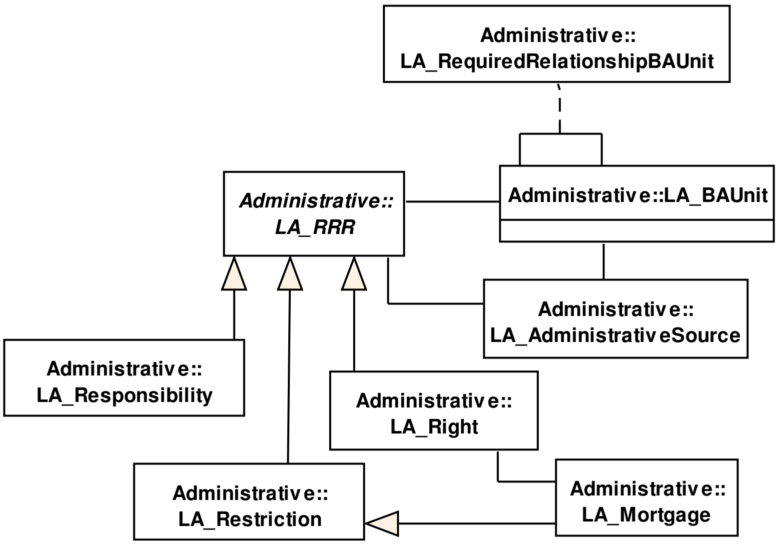

Figure 3 Classes of Administrative Package

3.4 Spatial Unit Package

The main class of the Spatial Unit Package is basic class LA_SpatialUnit, this is a single area (or multiple areas) of land and/or water, or a single volume (or multiple volumes) of space. *LA_Parcel is an alias for LA_SpatialUnit*, see Figure 4.

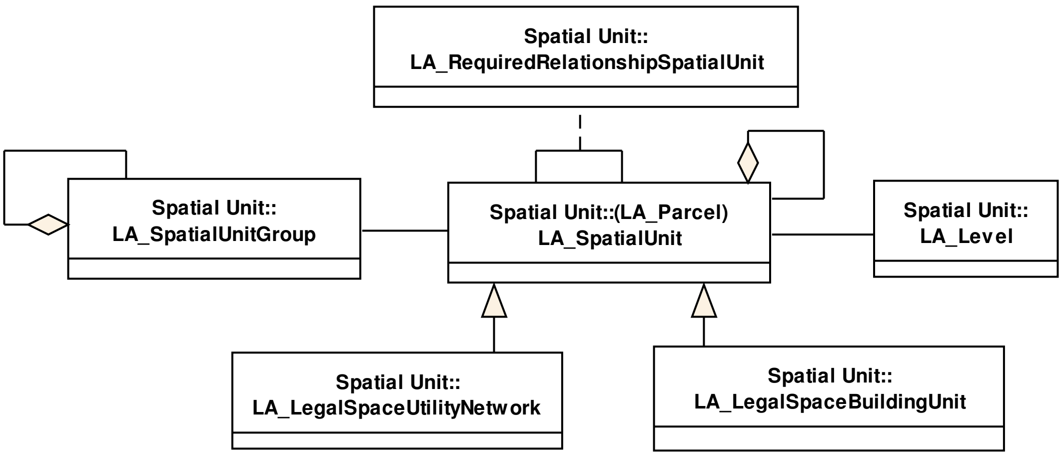

Figure 4 Classes of Spatial Unit Package

LADM supports either 2-dimensional (2D), 3-dimensional (3D), or mixed (2D and 3D) representations of spatial units, which may be described in text ("from this tree to that river"), or based on a single point, or represented as a set of unstructured lines, or as a surface (with or without topology), or as a 3D volume (Lemmen et al, 2010). Spatial units can be grouped in two forms: as spatial unit groups (any number of spatial units, considered as an entity, e.g. a municipality) or as sub spatial units, or *subparcels*, that is a grouping of a spatial unit into its parts. This is realized by an aggregation relationship of LA_SpatialUnit onto itself. Parts, in their turn, may be grouped into subparts (*subsubparcels*), and so on. The main difference is that there is no LA_BAUnit (and LA_RRR) directly attached to LA_SpatialUnitGroup, while this is the case for recursive grouping of LA_SpatialUnit (subparcels).

Spatial units have two specializations: building units (component of building concerning the legal, recorded or informal space of the physical entity) and utility networks (network describing the topology of a utility; this can modeled as a baunit). A level is a set of spatial units, with a geometric, and/or topologic, and/or thematic coherence: e.g. urban, rural, forest, railway cadastre. Or one level with formal and one level with informal and one level with customary rights.

Required relationships are explicit links between spatial units, and instances of class LA_RequiredRelationshipSpatialUnit. Sometimes there is a need for these links, when the geometry of the spatial units is not accurate enough to give reliable results, when applying spatial overlay techniques (e.g. a building, in reality inside a parcel, is reported to fall outside the parcel; the same applies to the geometry of a right, e.g. an easement). Required relationships override implicit relationships, established through spatial overlay techniques.

3.5 Surveying and Representation Subpackage

The four classes of the Surveying and Representation Subpackage are (1) LA_Point, (2) LA_SpatialSource, (3) LA_BoundaryFaceString, and (4) LA_BoundaryFace, see Figure 5.

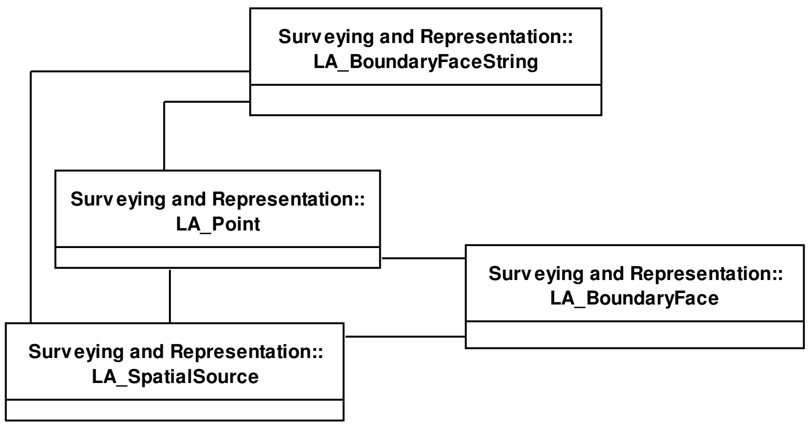

Figure 5 Classes of Surveying and Representation Subpackage

Points are 0 dimensional geometric primitives representing a position. Points can be acquired in the field (with classical surveys, or with satellite navigation systems), in an office, or compiled from various sources, for example using forms, field sketches, orthoimages, or orthophotos. The acquisition of points (a survey) may concern the identification of spatial units on a photograph, on an image, or on a topographic map; cycloramas or pictometry methods (multiple images from different angles) may also be used for that purpose.

A survey is documented with *spatial sources*. These may be the final (sometimes formal) documents, or all documents related to a survey. Sometimes, several documents are the result of a single survey. A spatial source may be official, or not (i.e. a registered survey plan, or an aerial photograph). Paper based documents (which may be scanned) can be considered as an integral part of the land administration system.

A set of measurements with observations (distances, bearings, etc.) of points, is an attribute of LA_SpatialSource. The individual points are instances of class LA_Point, which is associated to LA_SpatialSource. While it is not required that the complete spatial unit is represented, a spatial source may be associated to several points. Geodetic control points, including multiple sets of coordinates for points, and with multiple reference systems, are all supported in LADM.

2D and 3D representations of spatial units use *boundary face strings* as instances of class LA_BoundaryFaceString, and *boundary faces* (Lemmen et al 2010) as instances of class LA_BoundaryFace. Coordinates themselves either come from *points*, or are captured as linear geometry. LADM supports the increasing use of 3D representations of spatial units, without putting an additional burden on the existing 2D representations. Another feature of the spatial representation within LADM is that there is no mismatch between spatial units that are represented in 2D and spatial units that are represented in 3D.

3.6 Special Classes

The Class VersionedObject is introduced in LADM to manage and maintain historical data in the database. History requires, that inserted and superseded data, are given a time-stamp. In this way, the contents of the database can be reconstructed, as they were at any historical moment. The generic data type Oid is introduced in LADM to provide support for object identifiers.

3.7 Discussion

The LADM can be considered as a conceptual framework for the description of the current and future requirements and trends in Land Administration. Chapter 5 gives an overview. The focus of STDM is on 'people – land relationships', independently from the level of formalization, or legality of those relationships. From now on, with LADM and STDM, it is possible to register worldwide the information-related components of Land Administration (LA) in a standardized way. This opens the road to *a spatially enabled society*, as mentioned in (Williamson et al, 2010).

4. IMPLEMENTATION AND USE IN PRACTICE

When the LADM is finalised as an International Standard it can be used for as a basis for the design of Land Administration Systems. Modelling facilitates appropriate system development (and reengineering) and, in addition, it forms the basis for communication between different systems in different (parts of) organisations. This use of LADM in practice means that now, finally, application design can be based on GIS and database technology. Of course there is no difference if open source or commercial GIS and/or Database Management platforms are used for this purpose. When using standards, information can be exchanged in heterogeneous (commercial and open source) and distributed environments

Several country profiles have been created (some of them included in an annex of the draft standard) and other model use is being conducted e.g. the Land Parcel Identification Systems or the Social Tenure Domain Model (Augustinus, et al 2006, Augustinus 2010, FIG 2010). A part of the LADM SpatialUnit Package has been used in the INSPIRE Data Specification on Cadastral Parcels. The idea is that LADM will be fully integrated in this specification after its acceptance.

4.1 Country profiles

It is important to recognise that, although this is a land administration domain model, it is not intended to be complete for any particular country. It should be expandable and it is likely that additional attributes, operators, associations, and perhaps new classes, will be needed for a specific region or country. Furthermore it may be so that specific attributes or even classes are not needed in a region or country. Country profiles can be used for customizing LADM, to meet specific needs. An example is given here below in figure 6 (this is the country profile of the Netherlands, see Annex D in the DIS 19152). There are further country profiles from Portugal; Queensland, Australia; Indonesia; Japan and Hungary. Profiles for Korea and Cyprus are also available and may be included in final version of the standard.

The idea is that the country profile should not include different structures or solutions, where LADM has standard provisions. This is, among other places, expressed in the normative Annex A, the Abstract Test Suite, of the standard.

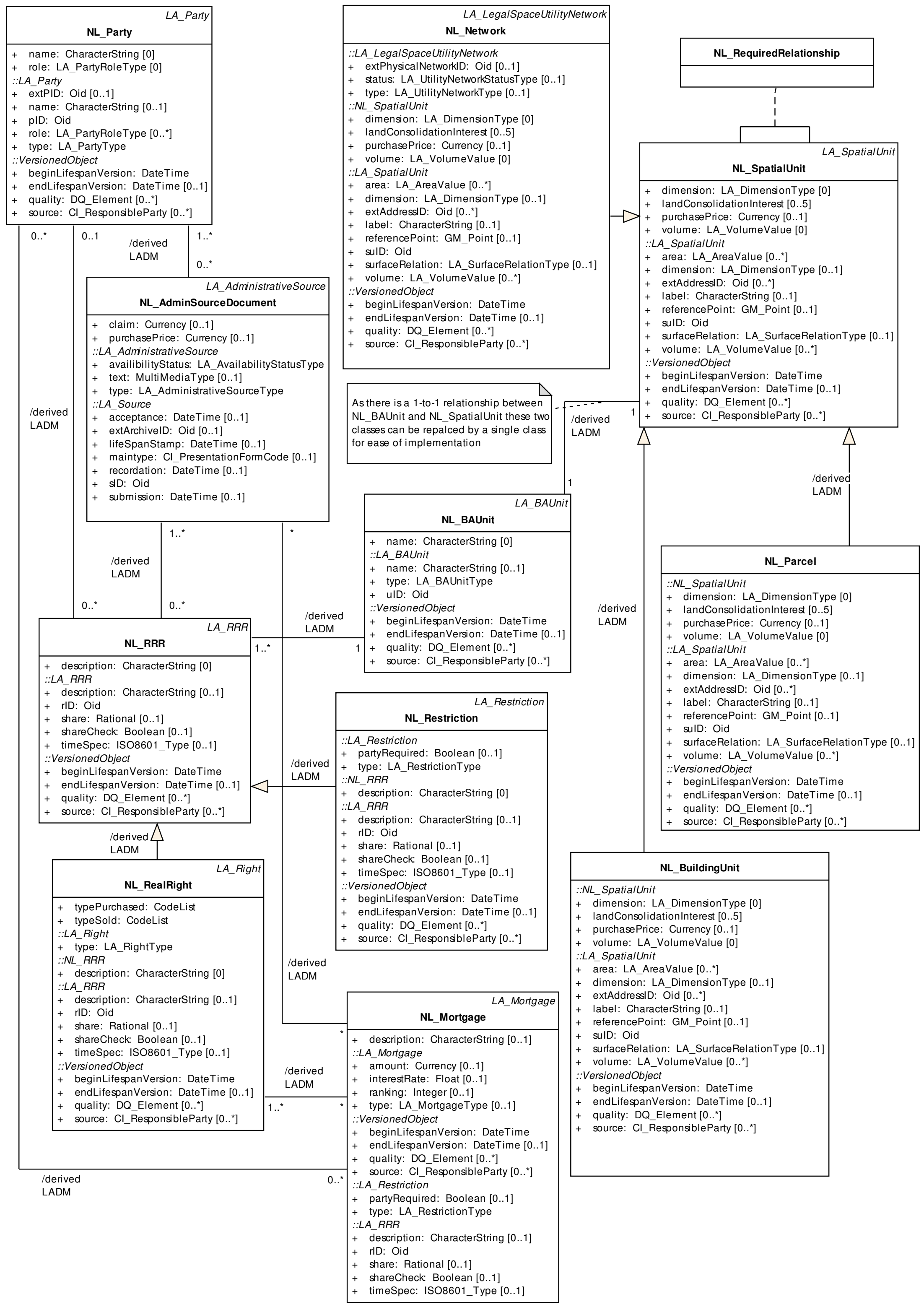

Figure 6 Country Profile of The Netherlands

4.2 The integration of LADM with the European Land Parcel Identification Systems (LPIS)

One of the aspects of the Common Agricultural Policy (CAP) of the European Union is to focus on the management of subsidies to farmers. For this purpose, member states have established Integrated Administration and Control Systems (IACS), including Land Parcel Identification Systems (LPIS) as the geographic component.

A data model has been designed that implies the collaboration or integration of LADM and LPIS. The standardization initiative in the area of LPIS (Sagris and Devos, 2008; CCM, 2009) by the Joint Research Centre (JRC) of the European Commission is used in this data model, in order to represent potentials for integration/collaboration between LADM and LPIS.

4.3 The Social Tenure Domain Model (STDM)

The security of tenure of people in slum areas or customary areas relies on forms of tenure different from individual freehold or other formal land rights. Most off register rights and claims are based on social tenures. UN HABITAT developed a continuum of land rights, which include rights that are documented as well as undocumented, from individuals and groups, from pastoralist, and in slums which are legal as well as illegal and informal.

This range of rights generally cannot be described relative to a parcel, and therefore new forms of spatial units are needed (sketch based, text based, point based, (unstructured) line based and polygon based apart from 'topological based'. A model has been developed to accommodate these social tenures, termed the Social Tenure Domain Model (STDM). The focus of STDM has been on the relationships between people and land, independently from the level of formalization, or legality of those relationships. It is a search for a model that should support all forms of land rights, social tenure relations, and overlapping claims to land (Augustinus, 2006). An instance level diagram is presented here in figure 7. The Ghana customary rights are based on an hierarchy of parties (King, Paramount Chief, Village Chief, Family Head, and Household Head), RRRs and BA/Spatial Units (Kingdom, Region, Village, Family SU, and Household SU)

A first prototype of STDM is available and was presented (and made available for testing) at the FIG Congress in Sydney, Australia, 2010. This is a pro-poor land information management system that can be used to support the land administration of the poor in urban and rural areas, which can also be linked to the cadastral system in order that all information can be integrated.

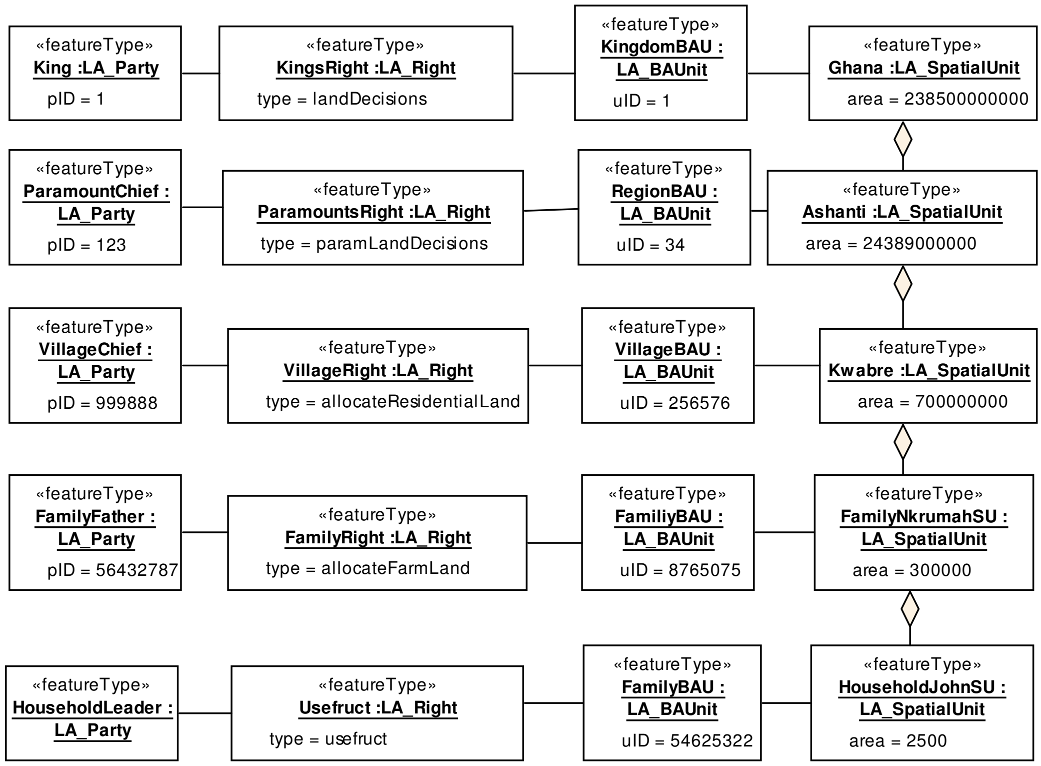

Figure 7 Customary rights in Ghana.

4.4 Inspire

The INSPIRE Directive requires to take existing standards into account (article 7 of the directive). Once adopted, the ISO/CEN 19152 standard should be taken into account if there are requirements and consensus to extend Data Specification for Cadastral Parcels. In case of ISO/CEN LADM, there was an excellent opportunity as both INSPIRE Cadastral Parcels (CP) and ISO/CEN LADM where under development at the same time. Through joint work between the INSPIRE Technical Working Group CP and the LADM Project Team this has been achieved. This ensured consistency between INSPIRE and LADM and resulted in a matching of concepts and compatible definitions of common concepts. Of course it must be remembered that there are differences in scope and targeted application areas; e.g. INSPIRE has strong focus on environmental users, while LADM has a multi-purpose character (supporting legal security, taxation, valuation, planning, etc.) and LADM is supporting both data producers and data users in these various application areas. Also, LADM has harmonization solutions for rights and owners of 3D cadastral objects (such as building or network reserves), which are currently also outside the scope of INSPIRE Cadastral Parcel. However, trough the intensive cooperation, it is now made possible that a European country may be compliant both with INSPIRE and with LADM. Further, it is made possible through the use of LADM to extend INSPIRE specifications in future, if there are requirements and consensus to do so. In order to 'proof' the compatibility, the ISO19152 document includes (in Annex G) a LADM-based version of INSPIRE cadastral parcels, showing that the INSPIRE

development fits within the LADM and that there are no inconsistencies. In INSPIRE context four classes are relevant:
– LA_Parcel as basis for CadastralParcel,
– LA_BAUnit as basis for BasicPropertyUnit,
– LA_FaceString as basis for CadastralBoundary,
– LA_SpatialUnitSet as basis for CadastralZoning.

4.5 FAO SOLA

The FAO Solutions for Open Land Administration (SOLA) project will promote affordable IT-systems that enable improvements in transparency and equity of governance. Started in June 2010, SOLA is a three year trust fund project, funded by the Government of Finland. Through the development and re-use of open source software, it aims to make computerised cadastre and registration systems more affordable and more sustainable in developing countries. Three countries (Samoa, Nepal and Ghana) have been identified for pilot implementation of the software. The LADM is being used as input for SOLA developments; see www.flossola.org**.**

5. EXPECTED FUTURE REQUIREMENTS FROM LAND GOVERNANCE

Expected future requirements as identified in Uitermark et al (2010), Bennet (2010) and Kalantari (2008) can be covered with LADM or with some extensions and adaptations. Kalantari and co-authors introduce the legal property

5.1 Many types of RRRs

In general it can be expected that many types of public restrictions need to be included in Land Administration (as far as not yet there); see also (Kaufmann and Steudler, 1998 and Williamson et al 2010). This includes planning zones under design or under implementation. The same holds for taxation zones or benefiting areas, for fair payments by the real beneficiaries, or limitations in land use because of environmental conditions related to restrictions in land use. In other zones land use may be allowed to intensify. Permits may be required in specific zones; the different types of permits allowing certain activities, should be as easily accessible as the restrictions, like erecting or changing a building, but also allowing certain land use. The fact that a factory is allowed certain activities can be seen as a nuisance by a potential house buyer nearby in the same way as for the facilities discussed later. Also specific financial benefits should be recorded.

The fact that land registration traditionally focuses on private land, private interests and restrictions, also means that in many countries state land, or land in the public domain, is not included in the land registries, or even left out on the cadastral map. It is a requirement to add those to come to complete cadastral coverage (see also Bennet, 2010).

The solution designed in the 1990s to administratively determine each effected parcel is now obsolete, and GIS overlaying of the two types of spatial objects is much more practical. If this is not possible because of the quality of spatial data the parcel based method can still be used of course. Different restrictions are determined by different social-economic and natural phenomena and each has its own spatial object representing their sphere of effect. 'Cadastre 2014' already foresaw this (Kaufmann and Steudler, 1998); see also van Oosterom (2006a) and further Kalantari et al (2008b). Kalantari et al further build on the 2014 approach by introducing so called 'Legal Property Objects' from a perspective of generic 'interests in land' instead of RRRs. 'Interests in land' as a generic term was introduced in FIG, 1995. Kalantari et al propose a close relationship between interest and the spatial dimension. The spatial representation can be in points, lines, polygons, etc. as in Augustinus (2006), there are further references in this article to other authors with similar proposals. All the representations covered in the LADM; including all types of restrictions (in the broad sense) with their own areas (see van Oosterom et al 2006a page 648). All restrictions and responsibilities are in principle related to (authentic) source documents.

5.2 Mature Information Infrastructure

The information society, which is currently in its infancy stage, will be more mature by the year 2020, with as a result several well established *domain standards, e.g. the LADM*, enabling meaningful information exchange at a global level, but also at a national or sub-national level, between different domains or disciplines. Information infrastructures will provide the environment for integrated and 'seamless' access to all these sources. Similar proposals can be found in Bennet et al (2010). Seamless means also "internationally seamless": seamless data across country or territory borders (with no international overlap or gaps), and all data accessible in the same client environment without bothering the end-users; even if sources or servers are different. This requires standards as the LADM. Part of LADM is being used in INSPIRE, see par 4.4 above.

Information infrastructures will provide the environment in which these sources can be maintained in a consistent manner. Domains need links with other domains, which require that updates take care of consistency with related registrations. For LA systems, as cornerstone of the information infrastructure, these links with other registrations are numerous, for example, persons, companies, addresses, buildings, rights, or topography. Besides 7*24 hours access over the network, this requires certain mechanisms to be in operation, like every registration must maintain history (in order to avoid 'dangling' references from outside, not aware of certain changes), update alert or notification systems must be established (in order to inform related registrations about changes, which may also need an update in the related registrations) and providing adequate solutions for performance and robustness; for example, via replicated, proxy servers. For an organization in order to rely, for its primary task, on a registration of another organization, some kind of 'information assurance' must be established: a legal and financial framework. In case of a failure, there will be compensation, which is proportional to the damage of having no access to required information. Also information related to facilities like schools, hospitals, sporting facilities, and public transport hubs zones are more fuzzy, and tends to be shown as concentric rings (or, more oddly shaped forms related to roads and railway lines) and become accessible via the SII. Service providers are increasingly making overviews of such facilities for clients, who are considering buying a certain house, and some of the information is made accessible through government websites. It will become possible to combine a large amount of such data on the fly. For good governance, such information should be more widely available within the public sector. Other interests, especially privacy, might call for some restraint in how much of this should be widely available on the web, also because many benefits are related more to the person of the beneficiary, than to the place he or she lives or works (even though this place might be a condition to get a certain benefit or permission).

Augmented reality applications, precise positioning and orientation: data must be accessible everywhere, all using authentic sources, but also for updating these sources by the community outside. Furthermore, mobile applications can read the successors of bar codes of id-cards to identify people, and digital fingerprints, or iris scans will be available in the field. These types of attributes are already included in the LADM.

5.3 Dynamic Process Models

Transaction processes in different countries will become more and more transparent and so more comparable. This will be the basis for the development of building stones to built transaction processes (or to include new components in existing processes) in a dynamic way depending on the local needs. Maintenance of historic data related to transactions and database updating will be better performed. This allows analyzing and predicts the effect of certain policies or economic developments on the land market). LADM has facilities in support maintenance of history of LA: time stamps, versioning, dates in transactions, availability of archives, external archives, etc. Also responsible (certified) parties in transactions (conveyors, lawyers, surveyors, etc. etc) can be related to the transactions for transparency reasons.

5.4 3D (and 4D, 5D) Space+Time+Scale Administration

The increasing complexity and flexibility of modern land use requires that LA systems will need an improved capacity to manage the third dimension. As the world is by definition not static, there will be a need in relation to the representation of the temporal (fourth) dimension, either integrated with the spatial dimensions, or as separate attribute(s). In the long term, an integrated 4D registration of all objects, will be the most effective solution (Van Oosterom et al, 2006; Döner et al, 2010). The *4D integrated space/time paradigm*, as a partition of space and time without gaps and overlaps (in space and time), is a very generic and solid basis. Initially, this approach may seam overkill, and only to be applied for some more complex objects such as construction works and utility networks. However, by the year 2020, the technological challenges related to 4D registration will be solved, and this will be the most effective base for registering all objects. The same is valid for 5D, where scale comes in.

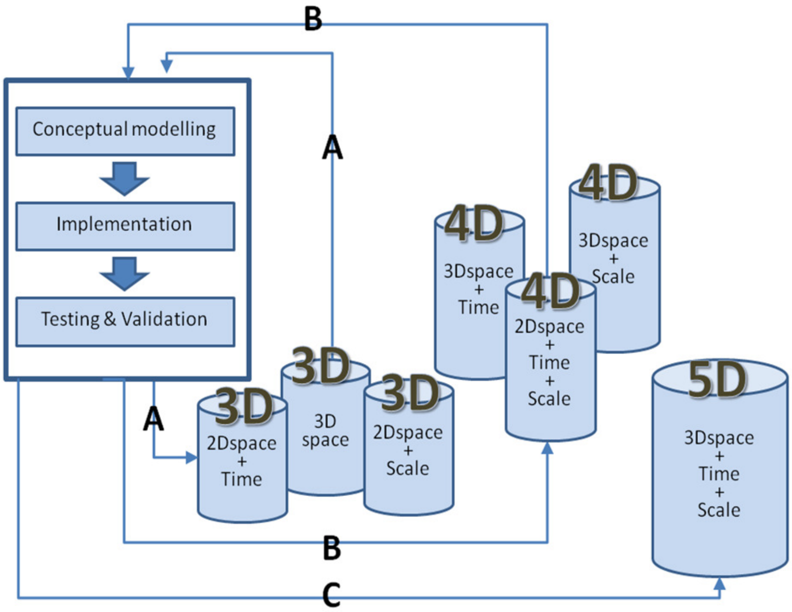

Figure 8 Integration the representation of 3D space and time (and perhaps even scale; see Van Oosterom and Stoter, 2010)

5.5 Spatial design and development

Today LA is mainly used in 'registration' mode: observations from reality are represented in the LA system. But it may be well situated to be used in 'design' mode: objects created/designed in the system are being implemented in reality. This implies: participation in decision making of the area to be included (also using many existing spatial data), participation in the design of zones where land use functions are allocated (requirements, wishes, agreements, complaints and acceptance by citizens), involvement in the implementation of the zoning plan (with new and temporal restrictions and responsibilities, permits, and maintenance issues). All this with mechanisms to avoid people losing land rights (also in customary areas or in areas where LA does not exist in this moment) and where governments can apply all kind of restrictions; in relation to carbon credits (see van der Molen, 2009) LADM has the flexibility to bring support in management of data for spatial design; new types of spatial units, RRRs or basic administrative units may be needed but can be easily included. In designing new spatial units, the future information infrastructure will be heavily used as the design requirements are related to many other geo-information sources, like soil and land value, or accessibility to roads and water. This will support decision making for food and energy provision.

5.6 New types of Rights, Restrictions and Responsibilities

LA systems need the flexibility to allow usage as starting point for a range of new registrations. A characteristic of all these new registrations is that somehow people, spatial objects or spatial phenomena (and the relationships between these) are important. This can be existing situations or situations under design or development. Emerging examples of this are: registration of groundwater quota (note that this has clearly a 3D and temporal character) (Ghawana et al, 2010), carbon credit quota registration (as a tool to assist in taking measures against global climate change), or rights of all kinds of natural resources (such as mining). But also the physical plans and the associated rights, restrictions and responsibilities they bring along, will belong to this category of 'new' registrations in LA systems. Instead of unrelated registrations, by the year 2020 society will benefit from a harmonized system of registrations of all these spatial and temporal objects and the involved rights, restrictions and responsibilities. Other attributes (e.g. energy labels for buildings) can also be introduced in a easy way in an LADM based approach.

5.7 Faster and More Direct Updating by Actors

The currently established update procedures will be simplified by the year 2020. For example, to split and sell a part of a parcel, require nowadays professionals, such as notaries, surveyors, and registrars, each performing certain sub-tasks. An early example of this was the developed prototype to add a boundary sketch by the notary as part of the transaction (Brentjes et al., 2004). Based on authenticated identification of persons and trusted reference material (e.g. high resolution and up-to-date geo-referenced imagery), seller and buyer will together, via web-services, draw the new boundaries of the split part of the parcel and complete the transaction, including payment. The required web-services and protocols are currently being developed and implemented; e.g. WFS-T (Web Feature Service with Transaction capabilities; OGC, 2010). The accuracy of images becomes so high that there may be no need for surveying in specific cases. Also Bennet (2010) mentions survey accurate cadastres as a future requirement. This development implies the representation of the same object in different versions with different accuracies and quality labels as supported in LADM. The role of the LA authorities will be to provide the required infrastructure, at least the LA part and the links to other parts of the geo-information infrastructure (GII), and perform quality control and validate transactions: "are all steps performed correctly?" Here new types of roles for responsible parties in relation to transactions come in.

5.8 Semantic Web-Based Content

The differences in (legal) concepts, terminology and languages which are used in the different LA systems are today still limiting the access and understanding of LA data in an international context (compare EULIS project; see Tiainen, 2004). However, legal concepts of the different countries will be formalized using semantic web technology, similar to all other kinds of knowledge. These formalized semantics are used in the mapping between the concepts and terminology from different countries, allowing the users to have access to all information in an unambiguous and understandable manner. The LADM is an excellent tool in support of such a development. It requires maintenance of codings and definitions for different RRRs under different jurisdictions and authorities (e.g. municipalities with responsibilities for spatial planning).

5.9 Monitoring Applications

Satellites can monitor changes in areas, which have been identified as world heritage sites: forest and nature, lakes, coast lines, glaciers, and polar zones. But also agriculture land, inundations, and draughts. This information can be linked to 'RRR' polygons and other GII layers for decision making in water and food provision, with attention to flora and fauna. It can also be used in case of illegal occupations or in case of overlapping claims; e.g. claims from indigenous people and claims from new farmers. All this is being supported by LADM in a flexible way; e.g. options to use levels or the option to use spatial units in many appearances without RRRs associated.

5.10 Community Driven Cadastral Mapping – OpenCadastreMap

The developments as pointed out before may look as enlarging the digital gap between the so called developed world and developing world. However, it is expected that ICT provides opportunities to avoid undesired developments (e.g. land grabbing, distribution of titles over land used by local communities to mining companies, agricultural industries and other ways of large scale land use and investments), where the local communities, who are often overruled by this, even in areas where those developments have been taking place for long time. Recognition of customary rights and of occupancy rights are relevant in formalization, apart from adjudication (which is time consuming and expensive). OpenCadastreMap is exploring the possibilities and dilemmas of participatory cadastral mapping by asking for instance the following questions: what will happen if people start uploading their land claims to the internet if the formal statutory systems lag behind? What are the social, legal and technical dilemmas? What are the economic implications? OpenCadastreMap is also investigating the problem solving power of social media. The issues mentioned above are of a multi-dimensional nature. OpenCadastreMap aims at bringing the knowledge of related LinkedIn Groups and other social media together.

In a setting like STDM data that comes in via OpenCadastreMap can be included. Of course different layers (in LADM called 'levels') are needed with collected and authorised data. Approaches are decentralised and participatory. Quality labels for accuracy are needed as available in LADM (Lemmen, 2010).

6. CONCLUDING REMARKS

A first step in the direction of domain modeling of LA has been made with LADM. Data needed for Land Administration in a broad sense can be represented in the LADM. There will be a next voting round within ISO on the further development of LADM. But in some countries, country profiles are already under development. It is expected that there will be a future need for the development of other non-LA domains. Within LADM these non-LA domains are explicitly indicated as external classes, such as persons (parties)[3], addresses, valuation, taxation, land use, coverage, physical utility networks, etc. Within the European

[3] Party may be an external class in LADM, this may relate to population register or company register. If this can not be implemented as external class it can be a LADM class. The same is valid for other external classes as mentioned in LADM.

Union, some of these domains are treated in INSPIRE, but certainly not all. Here lies an important role for FIG at a global scale (and in relationship with ISO).

Also, FIG could continue the work of ISO on O&M (ISO 19156) and make sure this is refined for cadastral surveying needs.

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