

The Foundation of Edition II of the Land Administration Domain Model

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The Foundation of Edition II of the Land Administration Domain Model

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SUMMARY

A new edition of the Land Administration Domain Model (LADM) is under further development in ISO/TC 211 on Geographic Information. The Committee is developing this new edition of the LADM – as multipart – working titles are as follows:

- Part 1 – Fundamentals
- Part 2 – Land Registration
- Part 3 – Marine Space Georegulation
- Part 4 – Valuation Information
- Part 5 – Spatial Plan Information
- Part 6 – Implementations

The decision to publish LADM Edition II as multipart had as a consequence that a New Work Item Proposal (NWIP) and a Working Draft (WD) have to be formulated for each Part. In 2020, the NWIP/WD have been submitted to ISO/TC 211 for Part 1 by Standards Australia (SA) with input from the author team on behalf of the FIG. The result of the voting was positive. Comments have been submitted, which will be processed and used in the next stage of the standard: the Committee Draft. It is planned that FIG will submit the NWIP for Part 2 before summer 2021. And it is expected that the same will happen this year for Parts 4 and 5. Those submissions are expected to be in close cooperation with other international professional organisations (i.e. IHO, RICS, OGC, etc.).

The editors of the LADM Edition II have the intention to publish papers on the developments on a regular basis. It is important to remember that these are ongoing developments with undergoing changes and may change at the time of the voting rounds. However, the main concepts and development will be communicated to the reader. This paper will focus on the developments and related discussions for Part 1 of the LADM Edition II. This part provides the definitions, a general overview of the model in its individual packages and a more detailed overview of the *LA_Source* (with a backwards compatible integrated administrative and spatial source added) and *VersionedObject* (now with standardized support for the bi-temporal model with intervals for both system and real world times) classes.

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1. INTRODUCTION

The Land Administration Domain Model (LADM) is a knowledge domain specific standard that provides a shared ontology, defining a common terminology for land administration.

The Land Administration Guidelines by the United Nations Economic Commission for Europe (UNECE) include one of the first widely accepted definition of land administration: “*the processes of recording and disseminating information about the ownership, value and use of land and its associated resources*” (UNECE, 1996). Based on this definition the LADM standard defines land administration as the “*process of determining, recording and disseminating information about the relation between people and land*”. Inclusion of land value and land use can be expected as well as the marine environment. It can be indicated from these definitions that land administration is a large field with several functions.

The development of the LADM Edition I was an initiative of the FIG) (Lemmen, 2012). The LADM and the Social Tenure Domain Model (STDM), a specialisation of LADM (see Augustinus et al., 2006; Augustinus, 2010; FIG/UN-Habitat, 2010), are currently under implementation in several countries, see FIG (2017), FIG (2018a), Lemmen et al. (2020). Moreover, LADM is also in use as such country profiles developed by various purposes (see Kalogianniet al., 2021), integration in the data specification of cadastral parcels in INSPIRE (INSPIRE, 2014) and basis for software development initiatives at FAO (FAO, 2011) (see also Lemmen, 2012).

LADM and STDM are also applicable in relation to the implementation of relevant parts of international guiding documents such as the New Urban Agenda (UN, 2017), the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security (FAO, 2012), the Continuum of Land Rights as from UN-Habitat (UN-Habitat, 2008, Teo and Lemmen, 2013), the Framework for Effective Land Administration A reference for developing, reformingn from the Expert Group on Land Administration and Management of the UN-GGIM (UN GGIM, 2019) and Fit-for-purpose land administration: guiding principles for country implementation (FIG/World Bank, 2014; UN-Habitat/GLTN/Kadaster, 2016). This fits, of course, very well into the context of implementation of the Sustainable Developments Goals (SDGs).

The editors of the LADM Edition II (representatives from FIG, Standards Australia and Standards Canada) have the intention to publish papers on the developments on a regular basis. It is important to notice that these are ongoing developments that may change at the time of the

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voting rounds and aim to communicate with the readers the fundamentals of each stage of standard's revision and allow them to keep track of the progress.

This paper aims to report the current stage of the LADM revision process within ISO/TC211. First, an overview of the LADM revision process is given in Section 2. Then, the paper will focus on the developments and related discussions for Part 1 of the LADM Edition II in Section 3 and will provide information on the general structure of the NWIP for the Part 2 in Section 4, followed by an overview of revision plans for 2021 in Section 4. The conclusions are in the last Section.

2. BACKGROUND

Although the LADM Edition I is extensively used (see Kalogianni et al., 2021) and is applicable for various different use cases and purposes, it still needs to be developed in order to better refine and cover land administration functions. The main developments with regard to LADM Edition II are:

1. During a UN-GGIM Meeting of the Expert Group on Land Administration and Management was held in March 2017, in Delft, The Netherlands it was concluded that a revision of the LADM Edition I is required in order to provide better tools for tenure security and better coverage of land administration, see UN-GGIM (2019).
2. As a result of the voting (ending March 2018) on the systematic review of ISO 19152:2012 it became clear that the majority of the ISO/TC 211 P-members expressed their wish for the revision. Also, a number of suggestions to be included in the revision was given. Some quotes from the document ISO/TC 211 N 4812 (ISO, 2018): inconsistencies with other referenced standards that need to be fixed, address global issues such as cadastre for oceans, issues as identified at TU Delft (<http://isoladm.org/StandardMaintenance>) should be considered, broader collaboration should be considered with the International Standardisation Organisation (ISO), the International Federation of Surveyors (FIG), the Open Geospatial Consortium (OGC), UN-Habitat, the Committee of Experts on Global Geospatial Information Management (UN-GGIM), World Bank, the Global Land Tool Network (GLTN), the International Hydrographic Organisation (IHO), the Royal Institute of Chartered Surveyors (RICS), etc., The integration of land use and land cover information within the LADM should be considered as well as the provision of 3D land administration in 3D (below, on and above the surface of the Earth) on land as well as at sea. And further mechanisms to exchange information (consider OGC's LandInfra/InfraGML), refinement of RRR, etc.
3. In order to revise LADM Edition I, FIG LADM Workshops were organized: one in Delft, the Netherlands, in March 2017 (FIG, 2017), one in Zagreb, Croatia in April 2018 (FIG, 2018a) and one more in Kuala Lumpur, Malaysia in October 2019 (FIG 2019). Considering the suggestions given by the TC 211 members and outputs of the workshops, a NWIP was prepared and submitted to the ISO/TC 211 in April 2018 by the FIG. The proposal includes the following main scheduled LADM extensions:

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- 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;
 - Improvement of current conceptual model. This includes formal semantics/ontology for the LADM code lists; more explicit 3D+time profiles; an extended and refined survey model and legal model;
 - Encodings/technical models. This includes further integration with BIM/IFC, GML, CityGML, LandXML, LandInfra, IndoorGML, RDF/linked data, GeoJSON, and:
 - Process models for survey procedures, map updating, transactions.
4. The NWIP, as submitted in April 2018 by the FIG to the ISO/TC 211, was not accepted by the ISO/TC 211. The reason was in the need for publication of the LADM Edition II as a multipart standard, see below under item 7.
 5. The ISO Stage 0 project started in May 2018 during the 46th Plenary Meeting Week of ISO/TC 211 Copenhagen, Denmark.
 6. There was a call for participants for the Stage 0 project on ISO 19152 LADM in September 2018. Then, during the 47th Plenary Meeting Week of the ISO/TC 211 in November, 2018 in Wuhan, China, a first meeting was held, regarding the approach and contents of the LADM Edition II, followed by a second meeting in June, 2019 in Maribor, Slovenia, during the 48th Plenary Meeting Week of the ISO/TC 211.
 7. In the the 48th Plenary Meeting Week of ISO/TC 211, Standards Council of Canada (SCC) proposed LADM Edition II as a multi-part. The following structure for the multi-part option (as multiple coherent packages with every part in separate standard) was agreed by the participants in that meeting:
 - Part 1 – Fundamentals
 - Part 2 – Land Registration
 - Part 3 – Marine Space Georegulation
 - Part 4 – Valuation Information
 - Part 5 – Spatial Plan Information
 - Part 6 – Implementations
 8. A White Paper on Land Administration prepared by the Domain Working Group Land Administration of the OGC (OGC, 2019) was discussed during the World Bank Conferences on Land and Poverty in March 2017 and in March 2018. A cooperation between OGC and ISO is expected to contribute to effective implementation and developments. The White Paper highlights the operationalisation of the LADM.
 9. The decision to publish LADM Edition II as multipart had as a consequence that a New NWIP/WD have to be formulated for each Part separately. In 2020, the NWIP/WD for Part 1 – Fundamentals has been submitted to ISO/TC 211 by Standards Australia (SA) amongst others from the author team on behalf of the FIG. The result of the voting was positive. Further, comments for the Part 1 NWIP/WD have been submitted by the ISO/TC211 Members. From January 2021 to April 2021, many issues and comments have been discussed during a number of virtual meetings, held with a working group of

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experts. After agreeing upon the comments, they will be further processed and used in order to create the next stage of the standard, namely the Committee Draft (CD).

3. LADM EDITION II PART 1 - FUNDAMENTALS

Today, three years have passed since the majority of the ISO/TC 211 P-members expressed the wish for the revision of LADM Edition I and more than one and a half year passed since the multipart decision has been taken. LADM Edition II will be backwards compatible with the Edition I. LADM Edition II will be based on the conceptual framework of ‘Cadastré 2014’ of the FIG (Kaufmann and Steudler, 1998), and the geospatial aspects followed by ISO/TC 211 conceptual models, as in LADM Edition I. This section is based on the NWIP/WD Part 1.

The Part 1 will be a high-level umbrella standard that supports all the other parts of the LADM Edition II. Part 1 will be present the fundamental notions and will define the basic components and relations shared by all objects created by land administration and provides an overview of all parts. The Part 1 will not only be backward compatible with the previous version of LADM but also with the IHO S-121 Maritime Limits and Boundaries standard (IHO, 2016), which will be used as basis when developing the Part 3 of LADM Edition II.

In LADM Edition I, the term land administration was used in the broad sense, including geographical spaces covering water and land, and elements above and below the surface of the earth. Considering the comment submitted by the Standards Council of Canada (SCC), a new term with a wider meaning is introduced: georegulation, which can be defined as an activity to delimit and assert control over 2D, 3D or 4D represented geographical (and temporal) spaces through regulations. Some of the geometry and spatial unit related definitions included in the LADM Edition I will not be defined in the Part 1 since they are not applicable for the certain other Parts (e.g. marine space). These definitions are boundary, boundary face, boundary face string, face, level and liminal spatial unit. In addition, the definition of right is changed as “formal or informal entitlement to own or do something”. It should be noted that there is an ongoing discussion on the definition of land.

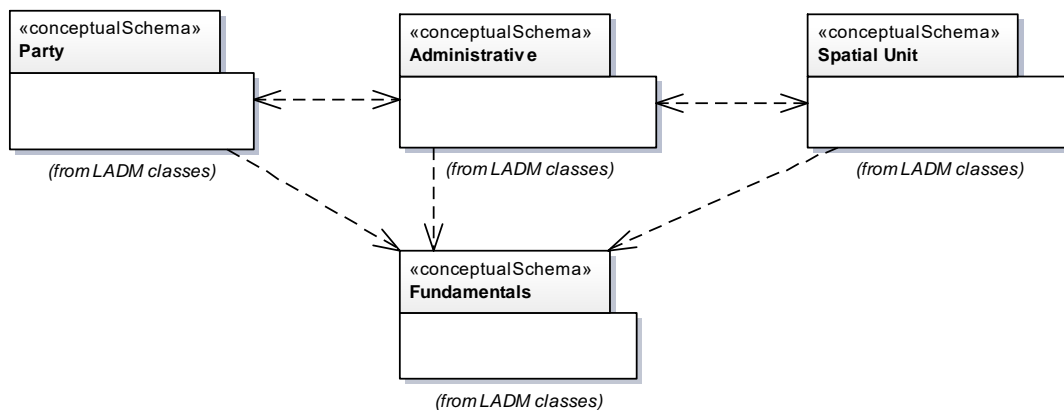


Figure 1 – Packages of the Part 1 of LADM Edition II

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This part will include four main packages of core LADM: Party, Administrative, Spatial Unit and Special Classes packages (see Figure 1). The Surveying and Representation Subpackage of the LADM Edition I will not be included in the main text of the Part 1 since it is not applicable for some of the other Parts (e.g. Marine Space Georegulation). As Part 1 is designed as a high-level standard, not all the classes of these packages will be included. For example, LA_Mortgage from the Administrative Package and LA_LegalSpaceBuildingUnit and LA_LegalSpaceUtilityNetwork from the Spatial Unit Package are not included in the main text of the Part 1, as these classes do not apply for some of the other Parts of LADM Edition II. It should be noted that Part 1 will not contain any information about the characteristics of any classes, except for the Special Classes Package.

Part 1 provides a general overview of the model in its packages as indicated above and a more detailed overview of the VersionedObject and LA_Source classes (see Figure 2). VersionedObject is an abstract class, and provides (optional) begin and (optional) end Lifespan and Valid Timestamps (optional) to the inheriting classes (see Figure 3). The class VersionedObject is used in the LADM to manage and maintain historical data in the database (ISO, 2012). History requires that inserted and superseded data, are given a time-stamp. All LADM classes inherit from VersionedObject (except for LA_Source). In this way, the contents of the database can be reconstructed, as they were at any historical moment (Thompson and Oosterom, 2021). There is one difference between the VersionedObject class of Editions I and II: the cardinality of the beginLifeSpanVersion changed from mandatory (1) to optional (0..1) and value type for this characteristic is defined as ‘continuing’, considering Canada’s comment to NWIP/WD Part 1.

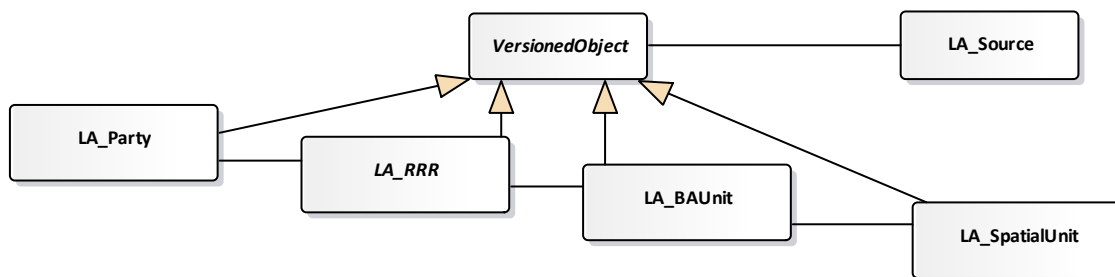


Figure 2 – Basic classes of the core LADM

The LA_Source class is introduced in Part 1 in order to support any kind of source. This class represents the event causing the changes in the registration (ISO, 2012). All the dates and times are system (or database) time, corresponding to the moment where the event was processed and stored in the system (Thompson and Van Oosterom, 2021). With the associations between VersionedObject and LA_Source, instances of sources can now be versioned, unlike the previous version of the LADM. Constraints assure correspondence of dates and times in VersionedObject and LA_Source (Figure 3). In addition VersionedObject and LA_Source have a second set of optional temporal attributes (beginValidLifespanVersion, endValidLifespanVersion, and acceptance), representing to the corresponding valid times in the real world (Thompson and Van Oosterom, 2021). Considering the comments from Standards

Canada and IHO, LA_Source class in the Part 1 is designed as a concrete class to support all sources that are not administrative or spatial.

Part 1 also introduces two generic data types: fraction and oid (see Figure 3). The former one provides support for fractions (e.g. $\frac{1}{2}$ or $\frac{3}{4}$), written as a pair of numbers, numerator and denominator, and the latter one provides support for object identifiers (ISO, 2012). In the committee meetings it is noted that the term fraction is a basic type, and it should be included in ISO 19103 and not in Part 1 of LADM Edition II. Therefore, a decision will be made for the fraction data type after contacting the ISO/TC 211 Terminology Maintenance Group (TMG) and the ISO/TC211 Harmonized Model Maintenance Group (HMMG).

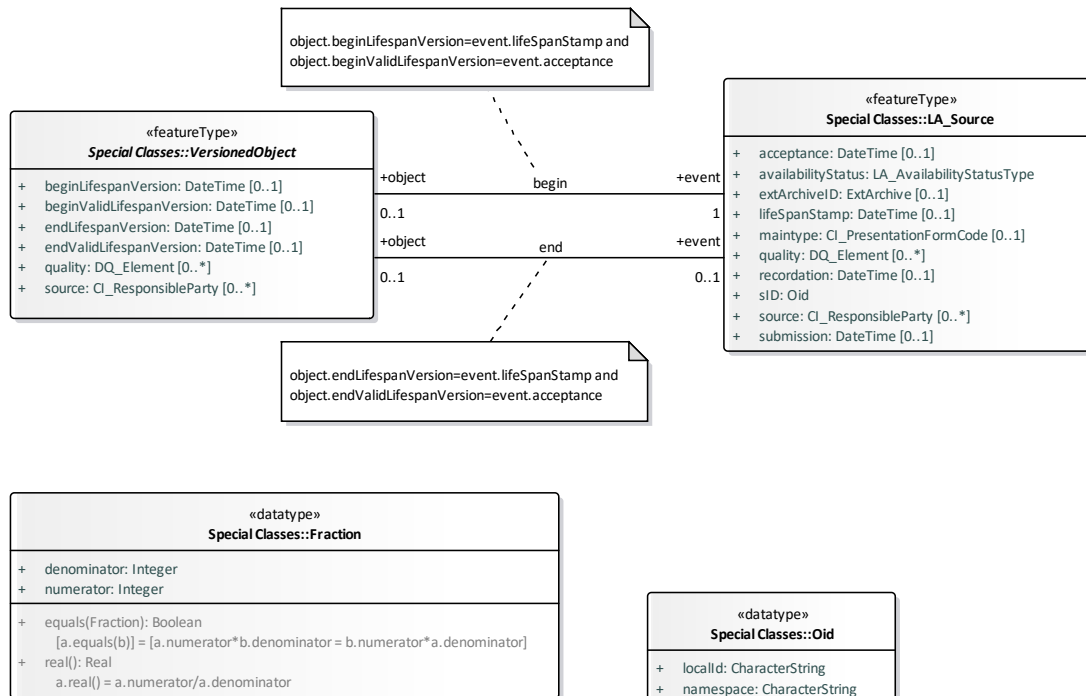


Figure 3 – Source, Versioned Object, Fraction and Oid

The second Edition of ISO 19152 will consist of the multiple parts, under the general title Geographic information — Land Administration Domain Model (LADM). After Part 1 (Fundamentals) additional parts may be added to address conceptual models of other application areas, such as Land Registration (a revision of IS 19152:2012), Marine Space Georegulation (Part 3), Valuation Information (Part 4), Spatial Plan Information (Part 5), and Support for Implementation (Part 6), including methodology for country profiles, technical encodings and registration of code list values. In the informative Annex D of the Part 1 an overview of the extended LADM packages is included (see Figure 4). After resolving the all comments received from the ISO/TC 211 Members, the Committee Draft (CD) for the Part 1 of ISO 19152 will be prepared and a voting will be organized by ISO/TC 211.

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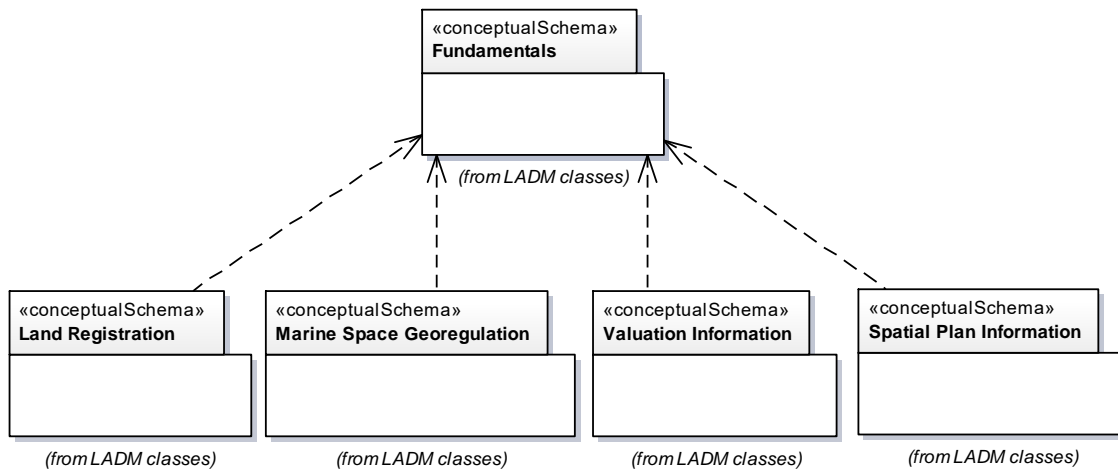


Figure 4 – Packages of the extended LADM with Marine Space, Valuation and Spatial Plan

4. LADM EDITION II PART 2 – LAND REGISTRATION

The LADM Edition I concentrated on Land Registration, which will now be addressed in the Part 2 of the LADM Edition II. Some of the existing parts of LADM Edition I are being refined in Part 2. The goal is that these refinements will add more semantics to the LADM. A good example of such improvements are the Refined Survey Model. The LADM refers to the ISO 19156:2011 Observations and Measurement Standard (ISO, 2011) which is essentially a survey model, though a very generic and one with limited capabilities. To facilitate a comprehensive spatial description, which incorporates the diverse elements of the survey component, such as different data acquisition and processing methods, spatial data formats, types of survey documents and the actions that can be applied to a spatial unit, a Refined Survey Model is required. In order to form such Model, an extended LA_SpatialSource class is suggested including support of various observation types accompanied by several new characteristics and corresponding code lists. The concept of ‘integrated source’ is introduced and is modeled as an association between the Administrative and the Spatial source classes. The refined survey model will benefit from part 6 ‘Survey’ the OGC 15–111r1 Land and Infrastructure Conceptual Model Standard (LandInfra) (OGC, 2016) and facilitate the interoperability between the two standards.

More attention will be given to provide semantically enriched, structured (thesaurus/ontology) and versioned code list in Part 2. Paasch et al. (2015) and Stubkjær et al. (2018) propose code lists as a mean of internationalisation by which the classes of the LADM may be related to a particular jurisdiction. It is planned to create a metamodel to describe the necessary components for the design of code lists (see, Stubkjær et al., 2019; 2021).

In LADM Edition I, the Spatial Unit Package and the Spatial Representation and Survey sub-package allows a set of possible representations of spatial units in 2D, 3D or mixed dimension

(integrated 2D and 3D), ranging from “text based” spatial unit to the “topology based” level encoding, providing a framework for categorisation of spatial units. Part 2 of the LADM Edition II will include refined 3D spatial profiles to support the full lifecycle of 3D objects (see Thompson et al., 2015, 2016; FIG, 2018b; Kalogianni et al., 2020).

Integration of the LADM with IndoorGML would allow 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, the LADM could establish a relationship between the indoor spaces and a party (Alattas et al., 2017). In Part 2 of LADM Edition II, the combined use of IndoorGML and LADM is proposed to be used in order to define the accessibility of the indoor spaces based on the ownership and/or the functional right for use.

Legal space is proposed to be linkable to physical objects in Edition II – by identifiers or re-use of descriptions of space. The users of indoor spaces create a relationship with the space depending on the type of the building and the function of the space. An IndoorGML-LADM model is one example of linking physical and legal objects one to another

The Global Land Indicators Initiative, (see UN Habitat/GLTN, 2017; 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 component alongside agreed global concepts and evidence-based approaches. There is a need for a foundation of a Land Administration Performance Index – which is a possible link to existing global frameworks or initiatives. In the Part 2 of the LADM Edition II, it is planned to provide a framework for indicators to be used for comparison and monitoring land administration performance.

It is also planned to provide an abstract level approach for modelling land administration processes in the Part 2. The LADM processes are organized per package and cover both data input and output data. Process models cover for survey procedures, map updating, and transactions – including blockchain. The other planned improvements for the Part 2 may be summarized as follows: The Social Tenure Domain Model will be in the formative part of the Part 2 and it is proposed to be presented “closer to the core” of LADM. The LA_LegalSpaceInfrastructure class will be introduced (see Figure 5), as a specialisation of LA_SpatialUnit, in order to cover infrastructure objects (e.g. tunnel). In addition, an optional geometry characteristic will be included in the class LA_SpatialUnit to cover all geometry types from ISO 19107.

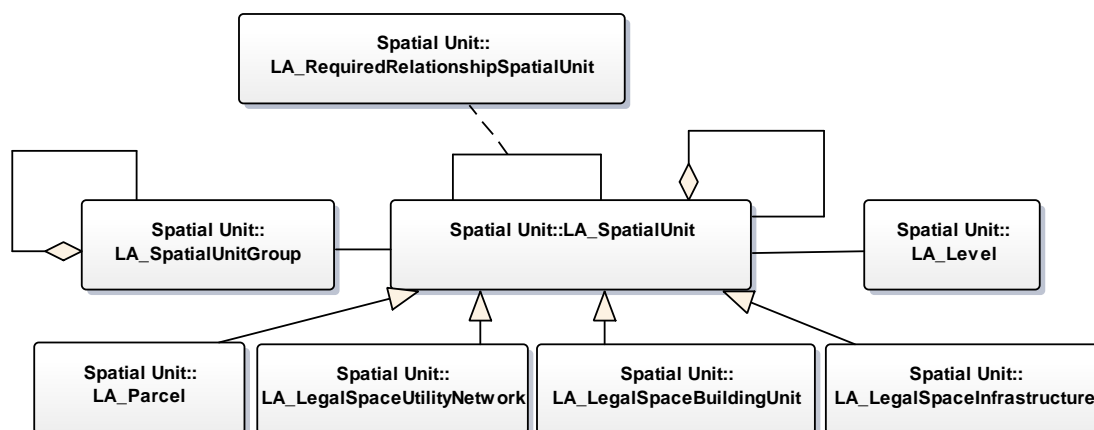


Figure 5 – Possible classes of the Part 2 – Land Registration of LADM Edition II

5. CONCLUSION

The Part 1 of LADM Edition II will be a high-level umbrella standard that present the fundamental definitions and basic components and relations shared by all objects created by land administration. In other to cover all objects related to land administration (e.g. marine space), a new term with wider meaning is introduced in the Part 1, ‘georegulation’, which can be defined as an activity to delimit and assert control over 2D, 3D or 4D represented geographical (and temporal) spaces through regulations.

LADM Edition II is expected to also add functionality for marine space georegulation, valuation information and spatial plan information (supporting spatial development). This makes the coverage of land administration / georegulation more complete by LADM Edition II, which is very important if the aim is to harmonize the models form these very related (sub)domains of land administration. This year NWIP/WD for Part 4 – Valuation Information and Part 5 – Spatial Plan Information will be submitted to ISO/TC 211.

The proposed LADM Edition II brings more complete support land management (also spatial planning, valuation, marine cadastre) and is closer to implementation (also technical models and processes).

REFERENCES

Alattas, A., Zlatanova, S., Van Oosterom, P., Chatzinikolaou, E., Lemmen, C. and Li, K.-J. (2017) Supporting Indoor Navigation Using Access Rights to Spaces Based on Combined Use of IndoorGML and LADM Models. *ISPRS International Journal of GeoInformation*, 6(12), 384.

Augustinus, C. (2010). Social tenure domain model: what it can mean for the land industry and for the poor. In *XXIV FIG International Congress: facing the challenges, building the capacity*.

Augustinus, C., Lemmen, C., & Van Oosterom, P. (2006). Social tenure domain model requirements from the perspective of pro-poor land management. In Proceeding of the 5th FIG regional conference.

FAO (2011). FAO FLOSS SOLA Data Dictionary for the SOLA Desktop Development Snapshot, version 1.0, August 24, 2011, (Prepared by Elton Manoku, Matthew Boafo and Neil Pullar).

FAO (2012) Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of Food Security. FAO, Rome, Italy.

FIG (2017) Documentation of the 6th Land Administration Domain Workshop, Delft, The Netherlands. <http://isoladm.org/LADM2017Workshop>

FIG (2018a) Proceedings 7th Land Administration Domain Workshop, Zagreb, Croatia, 11-13 April 2018. Editors: Christiaan Lemmen, Peter van Oosterom & Elfriede Fendel. ISBN 978-87-92853-69-1. International Federation of Surveyors FIG, Copenhagen, Denmark.

FIG (2019). Proceedings 8th Land Administration Domain Model Workshop, Kuala Lumpur, Malaysia, 1-3 October 2019. Editors: Peter van Oosterom, Christiaan Lemmen and Alias Abdul Rahman. International Federation of Surveyors FIG, Copenhagen, Denmark.

FIG (2018b). Best Practices 3D Cadastres. Extended version. Editor: Peter van Oosterom, ISBN 978-87-92853-64-6. International Federation of Surveyors FIG, Copenhagen, Denmark.

FIG/UN Habitat (2010). The Social Tenure Domain Model. FIG Publication 52, FIG Office, Copenhagen, Denmark (2010).

FIG/World Bank (2014) Fit-for-purpose land administration: Copenhagen, International Federation of Surveyors FIG, 2014. FIG Publication 60, ISBN 978-87-92853-11-0.

IHO (2016). S-121. Maritime Limits and Boundaries Product Specification.

INSPIRE D2.8.I.6. Data Specification on Cadastral Parcels-Technical Guidelines version 3.1, 17 April 2014.

ISO (2011) ISO 19156:2011, Geographic information — Observations and measurements. International Organization for Standardization (ISO). Geneva, Switzerland.

ISO (2012). ISO 19152:2012. Geographic information – Land Administration Domain Model (LADM). International Organization for Standardization (ISO). Geneva, Switzerland.

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ISO (2018). Result of voting on Systematic review ISO 19152:2012, Geographic information – Land Administration Domain Model (LADM), ISO/TC 211 N 4812, 22 May 2018.

Kalogianni, E., Dimopoulou, E., Thompson, R. J., Lemmen, C., Ying, S., & van Oosterom, P. (2020). Development of 3D spatial profiles to support the full lifecycle of 3D objects. *Land use policy*, 98(C).

Kalogianni, E.; Janečka, K., Kalantari, M., Dimopoulou, E., Bydłosz, J., Radulović, A., Vučić, N., Sladić, D., Govedarica, M., Lemmen, C. & van Oosterom, P. (2021). Methodology for the development of LADM country profiles. *Land Use Policy*, 105, 105380.

Kaufmann, J., & Steudler, D. (1998). *Cadastrre 2014: A vision for a future cadastral system*. J. Kaufmann, D. Steudler.

Lemmen, C., van Oosterom, P., Unger, E. M., Kalogianni, E., Shnaidman, A., Kara, A., Alattas, A., Indrajit, A., Smyth, K., Milledrogues, A., Bennett, R.M., Oukes, P., Gruler, H.C., Casalprim, D., Alvarez, G., Aditya, T., Ary Sucaya, K.G., Morales Guarin, M.J., Balas, M., Zulkifli, N.A. & de Zeeuw, C. J. (2020). The land administration domain model: advancement and implementation. In (Cancelled) Annual World Bank Conference on Land and Poverty 2020: Institutions for Equity & Resilience.

Lemmen, C., Van Oosterom, P. & Bennett, R. (2015). The land administration domain model. *Land use policy*, 49, 535-545.

Lemmen, C. (2012) A domain model for land administration. Delft, Technical University Delft (TUD), University of Twente Faculty of Geo-Information and Earth Observation (ITC), 2012. ITC Dissertation 210, ISBN 978-90-77029-31-2.

OGC (2016). OGC Land and Infrastructure Conceptual Model Standard (LandInfra). (Version 1.0, Publication Date: 2016-12-20), Editor: Paul Scarponcini, Contributors: HansChristoph Gruler (Survey), Erik Stubkjær (Land), Peter Axelsson, Lars Wikstrom (Rail).

OGC (2019). OGC White Paper on Land Administration. Editors: Christiaan Lemmen, Peter van Oosterom, Mohsen Kalantari, Eva-Maria Unger and Cornelis de Zeeuw. External identifier of this OGC document: <http://www.opengis.net/doc/wp/land-admin> Internal reference number of this OGC document: 18-008r1. Open Geospatial Consortium.

Paasch, J. M., van Oosterom, P., Lemmen, C. & Paulsson, J. (2015) Further modelling of LADM's rights, restrictions and responsibilities (RRRs). *Land use policy*, 49(2015), 680-689.

Stubkjær, E., & Çağdaş, V. (2021). Alignment of standards through semantic tools—The case of land administration. *Land Use Policy*, 104, 105381.

The Foundation of Edition II of the Land Administration Domain Model (11163)
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FIG e-Working Week 2021
Smart Surveyors for Land and Water Management - Challenges in a New Reality
Virtually in the Netherlands, 21–25 June 2021

Stubkjær, E., Gruler, H.C., Simmons, S., Çağdas, V. (2019). Code list management supported through a controlled domain vocabulary. 8th Land Administration Domain Model Workshop, 1 - 3 October 2019, Kuala Lumpur, Malaysia.

Stubkjær, E., Paasch, J. M., Çağdaş, V., Van Oosterom, P., Simmons, S., Paulsson, J. & Lemmen, C. (2018). International Code List Management – The Case of Land Administration. In: Proceedings of the 7th International FIG Workshop on the Land Administration Domain Model 11-13 April 2018, Zagreb, Croatia.

Teo, C. & Lemmen, C. (2013) The LADM and the continuum of land rights. In: Proceedings of the 5th Land Administration Domain Model workshop, 24-25 September 2013, Kuala Lumpur, Malaysia.

Thompson, R., & Van Oosterom, P. (2021). Bi-temporal foundation for LADM v2: Fusing event and state based modelling of Land administration data 2D and 3D. Land Use Policy, 102, 105246.

Thompson, R., Van Oosterom, P., Karki, S. & Cowie, B. (2015). A Taxonomy of Spatial Units in a Mixed 2D and 3D Cadastral Database. FIG Working Week 2015.

Thompson, R., Van Oosterom, P, Soon, K.H. & Priebbenow, R. (2016). A Conceptual Model supporting a range of 3D parcel representations through all stages: Data Capture, Transfer and Storage. In: FIG Working Week 2016 – Recovery from Disaster, Christchurch, New Zealand, May 2-6, 2016.

UN (2016). New Urban Agenda. Endorsed by the United Nations General Assembly at its Sixty-Eighth Plenary Meeting of the Seventy-First Session on 23 December 2016. ISBN: 978-92-1-132731-1.

UN ECOSOC and African Union (2016). Facing the Challenges of Land Monitoring in the Framework and Guidelines on Land Policy in Africa – Towards Agenda 2063 and the 2030 Agenda for Sustainable Development.

UN Habitat/GLTN (2017). Sourcebook for Operationalisation of Global Land Indicators. Global Land Indicators Initiative (GLII) Working Paper Number 4. Nairobi.

UNECE. Land Administration Guidelines with Special Reference to Countries in Transition; United Nations Economic Commission for Europe: Geneva, Switzerland, 1996.

UN-GGIM (2019). Framework for Effective Land Administration – A reference for developing, reforming, renewing, strengthening or modernizing land administration and management systems. Expert Group on Land Administration and Management United Nations Committee of Experts on Global Geospatial Information Management (UNGGIM).

The Foundation of Edition II of the Land Administration Domain Model (11163)
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FIG e-Working Week 2021
Smart Surveyors for Land and Water Management - Challenges in a New Reality
Virtually in the Netherlands, 21–25 June 2021

UN-HABITAT (2008). Secure land rights for all. Nairobi, Kenya, United Nations Human Settlements Programme.

UN-Habitat/GLTN/Kadaster (2016). Fit-for-purpose land administration: guiding principles for country implementation: e-book. Nairobi, United Nations Human Settlements Programme (UN-HABITAT).

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The Foundation of Edition II of the Land Administration Domain Model (11163)
Christiaan Lemmen, Alattas Abdullah (Saudi Arabia), Agung Indrajit (Indonesia), Kalogianni Eftychia (Greece),
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FIG e-Working Week 2021
Smart Surveyors for Land and Water Management - Challenges in a New Reality
Virtually in the Netherlands, 21–25 June 2021

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The Foundation of Edition II of the Land Administration Domain Model (11163)

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FIG e-Working Week 2021

Smart Surveyors for Land and Water Management - Challenges in a New Reality

Virtually in the Netherlands, 21–25 June 2021

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FIG e-Working Week 2021

Smart Surveyors for Land and Water Management - Challenges in a New Reality
Virtually in the Netherlands, 21–25 June 2021

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FIG e-Working Week 2021

Smart Surveyors for Land and Water Management - Challenges in a New Reality

Virtually in the Netherlands, 21–25 June 2021