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SUMMARY

The first edition of the Land Administration Domain Model (LADM) has been available as a formal International Standard since the 1st of December 2012, published as ISO 19152:2012. It is based on / makes use of a number of standards, in particular those published by ISO/TC 211 and, of course, other committees. In addition, non-ISO standards and international guidelines related to land administration have been used as much as possible in the development of LADM Edition I.

The systematic review of LADM Edition I has been officially launched and the process of developing LADM Edition II is now underway. The new edition not only refines the content of LADM Edition I, but also expands the scope to include marine georegulation, valuation information, spatial plan information and implementation. As a result, LADM Edition II is based on more standards, not only because of its expanded scope, but also because of the standards published after LADM Edition I and the principle of reusing existing standards wherever possible.

Since the publication of LADM Edition I, it has been widely recognised by the international community and implemented by several countries. It is also applicable to the implementation of relevant parts of international standards, guidelines and frameworks, as well as the Sustainable Development Goals (SDGs). LADM Edition II has somewhat more links to international standards, guidelines and frameworks, as its scope is broader than Edition I.

The purpose of this paper is to document which standards LADM Edition II is based on and associated with, which guidelines and frameworks are in some way related to LADM.

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1. INTRODUCTION

The Technical Committee 211 (TC 211) of the International Organisation for Standardisation (ISO) publishes standards for data management in the field of digital geographic information related to objects or phenomena that are directly or indirectly associated with a location relative to the Earth (ISO/TC 211, 2023). One of the standards of ISO/TC 211 is the Land Administration Domain Model (LADM), which has been available as a formal International Standard since the 1st of December 2012, published as ISO 19152:2012. LADM Edition I focuses on the part of land administration that is interested in rights, responsibilities and restrictions affecting land, and the geometrical (geospatial) components thereof (ISO, 2012). LADM Edition I is based on a number of standards, in particular those published by ISO/TC 211 and, of course, other committees, as well as standards published by other international bodies and guidance documents published by land administration communities.

Five years after the publication of LADM Edition I, discussions for a systematic revision were initiated during the UN-GGIM Expert Group Meeting on Land Administration and Management in Delft, the Netherlands, in March 2017, and it was concluded that a revision of LADM Edition I is needed to provide better tools for tenure security and better coverage of land administration, see UN-GGIM (2020). The systematic review includes not only refining the content of LADM Edition I, but also expanding the scope to include marine georegulation, valuation information, spatial plan information and implementation (Lemmen et al., 2019). As a result, LADM Edition II is based on more standards, not only because of its expanded scope and the refinement of existing scope, but also because of the standards published after LADM Edition I and the principle of reusing existing standards wherever possible. There is a long list of standards here also for Part 3, 4 and 5 of LADM Edition II. Part 3 is based on the existing International Hydrographic Organization (IHO) standards, namely IHO S-100 the Universal Hydrographic Model and IHO S-121 Maritime Limits and Boundaries (IHO, 2018, 2019; Beaupré, 2022). Part 4 adopted several terms and definitions from technical standards of the International Association of Assessing Officers, OGC's LandInfra and the International Property Measurement Standards (IPMS): All Buildings (IPMSC, 2023) while Part 5 benefits from the conceptual framework of Plan4all (Čerba, 2010).

Since its publication, the LADM and its specialization, the Social Tenure Domain Model (STDM), have been widely recognised and implemented by several countries. Moreover, LADM and STDM are also applicable in relation to the implementation of relevant parts of international guidance documents such as the New Urban Agenda (UN, 2016), the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security (FAO, 2012), UN-HABITAT's Secure Land Rights for All (UN-HABITAT, 2008), the UN-GGIM Expert Group on Land Administration and Management's Framework for Effective Land Administration A reference for developing,

reforming, renewing, strengthening, modernizing, and monitoring land administration (UN-GGIM, 2019) and Fit-for-Purpose Land Administration: Guiding principles for country implementation (UNHabitat/GLTN/Kadaster, 2016). This, of course, fits very well into the context of the implementation of the Sustainable Development Goals (SDGs).

This paper aims to document which standards LADM Edition II is based on and associated with, and which guidelines and frameworks are related to LADM in some way (e.g., LADM based on this guideline, this guideline refers to LADM, or LADM can be used to implement this guideline). The remainder of the paper is organized as follows: Section 2 explores the relationships between the parts of LADM Edition II and other international standards. Section 3 examines which and how the international guidelines and frameworks relate to LADM Edition II. Section 4 concludes the paper.

2. LADM AND OTHER INTERNATIONAL STANDARDS

The development of LADM Edition I is based as much as possible on the standards published by ISO/TC 211. In fact, this approach is actually followed by all ISO standards including ISO/TC 211 as well as the standards published by other standard setting bodies such as Open Geospatial Consortium (OGC). This approach avoids the production of repetitive standards in terms of terms, concepts, definitions and models; enables the development of interoperable standards and paves the way for sustainable standardization. This approach has also been followed in the development of LADM Edition II.

ISO documents, including ISO/TC 211 standards, are all subject to systematic review. For an international standard, this period is five years (ISO, 2023a). Between the publication of LADM Edition I and the start of development of LADM Edition II, a number of standards have been reviewed/updated. As a result, the standards on which LADM is based may differ between the editions. The standards on which LADM Edition I is based are listed in the normative references section. The approach to referencing normative references in ISO standards changed after LADM Edition I was published. All ISO standards must be based on a set of requirements. According to this new approach, a normative reference covers only those standards that are cited in at least one requirement. If a standard refers to another standard in the main text but not in a requirement, that standard should be cited in the references section. Therefore, the number of normative references in LADM Edition II Part 1 and Part 2 is less than in LADM Edition I. However, LADM Edition II Part 1 and Part 2 refer to more standards than in Edition I. It should be noted that the content of LADM Edition I is covered in Part 1 and Part 2 of LADM Edition II with refinements and extensions.

2.1 LADM Edition II Part 1

The standards, to which both the LADM Edition I and the LADM Edition II Part 1 and Part 2 used as a normative reference are: ISO 19103, ISO 19105, ISO 19107 and ISO 19109. As all the other parts of LADM Edition II (namely Part 2, 3, 4, and 5) are based on Part 1, the normative references in Part 1 are also normative for the other parts mentioned. In particular, Part 3 is based on Part 1, while Part 4 and Part 5 are based on both Part 1 and Part 2.

The terms and definitions used in the development of LADM Edition II Part 1 are listed in Table 1.

Table 1. Terms used from other standards and guidance document in LADM Edition II Part 1

Standard	Term	Definition of the term
ISO 19101-1:2014	Feature	Abstraction of real-world phenomena
ISO 19105:2022	Abstract test suite	Set of conformance classes that define tests for all requirements of a specification
ISO 19106:2004	Profile	Set of one or more base standards or subsets of base standards, and, where applicable, the identification of chosen clauses, classes, options and parameters of those base standards, that are necessary for accomplishing a particular function
ISO/CD 19135:2023	Register	Managed collection of information
ISO/CD 19135:2023	Register system (Registry)	Information system on which a register is maintained
ISO 19156:2023	Feature type	Class of features having common characteristics
ISO/IEC 8824-1:2021 (adapted from)	Object identifier (Oid)	Generic object identifier providing support in object identification
ISO/IEC Guide 2:2004	Regulation	Document providing binding legislative rules, that is adopted by an authority
UNECE Land Administration Guidelines with special reference to countries in transition (Adapted)	Land administration	Process of determining, recording and disseminating information about the relationship between people and land

The standards and their relevant parts used in the development of the Part 1 data model are listed in Table 2. The standards in bold are the normative references in Part 1.

Table 2. Standards used in the LADM Edition II Part 1 data model and their relevant parts

Standard	Class
ISO 19103:2015 Geographic information — Conceptual schema language	DateTime, CharacterString, Integer
ISO 19105:2022 Geographic information — Conformance and testing	- (Abstract test suite)
ISO 19106:2004 Geographic information — Profiles	- (Abstract test suite)
ISO 19107:2019 Geographic information — Spatial schema	- (Geometric elements)
ISO 19109:2015 Geographic information — Rules for application schema	- (General future model)
ISO 19115-1:2014 Geographic information — Metadata — Part 1: Fundamentals	CI_Responsibility, CI_PresentationFormCode
ISO 19157-1:2023 Geographic information — Data quality — Part 1: General requirements	QualityElement

One of the most used standards in data model of the LADM is *ISO 19103 Geographic Information — Conceptual schema language*. While the 2005 version (ISO/TS 19103:2005) is used in LADM Edition I, the 2015 version is utilized in LADM Edition II (ISO 19103:2015). This standard "*provides rules and guidelines for the use of a conceptual schema language within the context of geographic information*" (ISO, 2015a). ISO 19103 includes interface

classes that define textual information (i.e., CharacterString), timestamp information (i.e., DateTime), logical information (i.e., Boolean), numbers (i.e., Decimal, Integer, Real), truth (i.e., Boolean) and measure (i.e., Area, Volume, Distance, Angle, Currency), see Figure 1. It should be noted that only CharacterString and DateTime classes are utilized in Part 1 (how this standard is used in the other relevant parts is shown in Tables 4, 6, 8 and 10). ISO 19103 is currently under systematic review. If there are any changes to this standard that apply to LADM, these will be taken into account in the development of LADM Edition II.

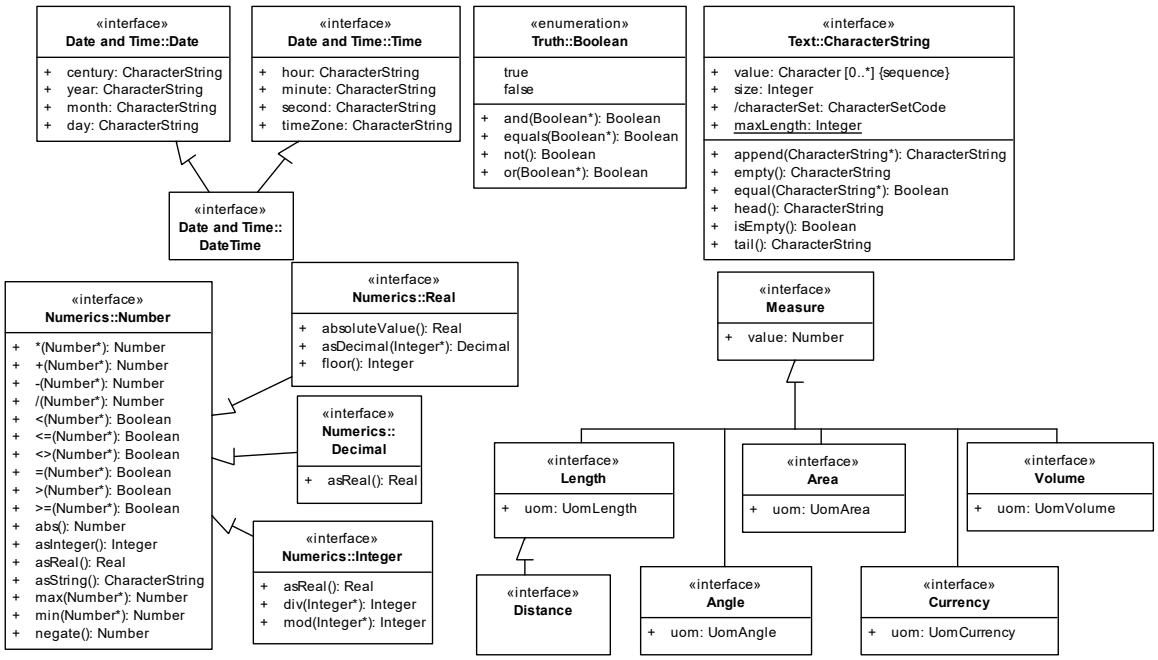

Figure 1. The ISO 19103 classes used in the development of LADM (ISO, 2015)

ISO 19105 Geographic information — Conformance and testing is another standard that LADM utilized for testing conformance to LADM. This standard "*provides a framework for specifying abstract test suites composed of abstract test cases grouped in conformance classes and for defining the procedures to be followed during conformance testing*." Annex A of LADM Edition I and of each part of LADM Edition II, which specifies how to test whether a particular application schema, such as a country profile, is conformant with the LADM. The general approach of the conformance testing by ISO 19105:2022 is shown in Figure 2 (ISO, 2022a). It should be mentioned here that to develop an application schema for all parts of LADM Edition II, the guidance provided by *ISO 19106 Geographic information — Profiles* should be followed. ISO 19106:2004 defines "*the concept of a profile of the ISO geographic information standards developed by ISO/TC 211 and to provide guidance for the creation of such profiles.*" (ISO, 2004).

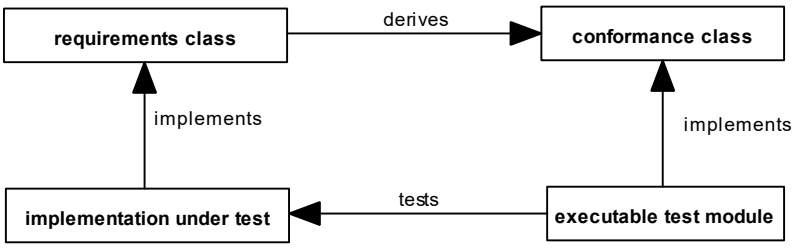

Figure 2. The general approach of the conformance testing of ISO 19105 (ISO, 2022a)

ISO 19107 Geographic information — Spatial schema is a crucial standard for LADM as it "*specifies conceptual schemas for describing the spatial characteristics of geographic entities, and a set of spatial operations consistent with these schemas. It treats "vector" geometry and topology.*" (ISO, 2019a). Part 1 uses this standard to represent geometric elements. However, since Part 1 does not contain detailed information about the spatial parts of LADM, in other words, since Part 1 does not include any attributes, operations or constraints other than the LA_Source and VersionedObject classes, the use of ISO 19107 in LADM is mentioned in the Part 2 section of this paper.

ISO 19109:2015 Geographic information — Rules for application schema define "*rules for creating and documenting application schemas, including principles for the definition of features.*" All LADM parts addressing land administration and georegulation (19152 series of standards) make use of the generic general feature model as described in ISO 19109 (ISO, 2015).

ISO 19115-1:2014 Geographic information — Metadata — Part 1: Fundamentals defines ISO "*the schema required for describing geographic information and services by means of metadata*" (ISO, 2014). LA_Source class is introduced to provide support for sources in land administration in Part 1. This class utilizes the ISO 19115-1 to represent responsible organization and responsible party of a source (i.e., CI_Responsibility), and type of document (i.e., CI_PresentationFormCode), see Figure 3.

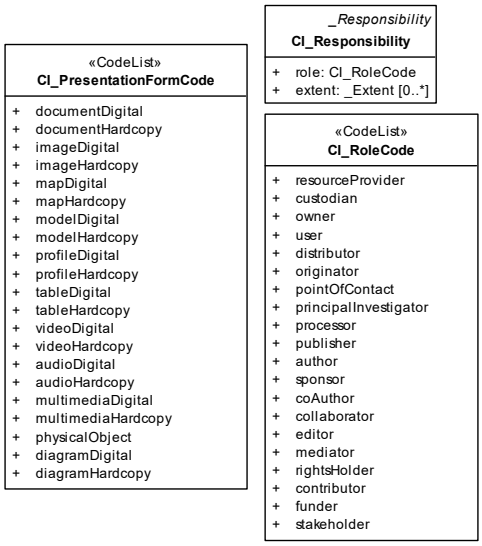

Figure 3. CI_Responsibility and CI_PresentationFormCode from 19115-1 (ISO, 2014)

The last standard referred in Part 1 is *ISO 19157-1:2023 Geographic information — Data quality — Part 1: General requirements*, which provides "*principles for describing the quality of geographic data*" (ISO 2023c). This standard is used in the data model of Part 1 to represent quality of a specific version of a source (i.e., QualityElement). LADM Edition I refers to ISO 19115:2003 for quality (i.e., DQ_Element), but quality information is now included in ISO 19157-1. For QualityElement and its subclasses (i.e., Completeness, LogicalConsistency, ThematicQuality, TemporalQuality, and PositionalAccuracy), see Figure 9 in the next subsection.

2.2 LADM Edition II Part 2

LADM Edition II Part 2 Land registration is based on Part 1. The terms and definitions used from other standards in the development of LADM Edition II Part 2 are listed in Table 3. As the Surveying and Representation subpackage of the Spatial Units package is introduced in Part 2, the terms referred to are related to geometric representations.

Table 3. Terms used from other standards in LADM Edition II Part 2

Standard	Term	Definition of the term
ISO 19107:2019	Boundary	Set that represents the limit of an entity
ISO 19107:2019	Face	2-dimensional topological primitive
ISO 19136:2020	Point	0-dimensional geometric primitive, representing a position

The standards and their relevant parts used in the development of the Part 2 data model are listed in Table 4. The standards in bold are the normative references in Part 2.

Table 4. Standards used in the LADM Edition II Part 1 data model and their relevant parts

Standard	Class
ISO 19103:2015 Geographic information — Conceptual schema language	CharacterString, Boolean, DateTime, Real, Integer, Area, Volume, Angle
ISO 19105:2022 Geographic information — Conformance and testing	- (Abstract test suite)
ISO 19106:2004 Geographic information — Profiles	- (Abstract test suite)
ISO 19107:2019 Geographic information — Spatial schema	Geometry, Point, Curve, Surface, PointCloud SetMask, DimensionExtension
ISO 19109:2015 Geographic information — Rules for application schema	- (General future model)
ISO 19111:2019 Geographic information — Referencing by coordinates	OperationMethod
ISO 19115-1:2014 Geographic information — Metadata — Part 1: Fundamentals	LI_Lineage
ISO 19156:2023 Geographic information — Observations, measurements and samples	Process
ISO 19157-1:2023 Geographic information — Data quality — Part 1: General requirements	AbsolutePositionalAccuracy
ISO 4217:2015 Codes for the representation of currencies	Currency
ISO/IEC 5218:2022 Information technology — Codes for the representation of human sexes	- (Sex types)
ISO 8601-2:2019 Date and time — Representations for information interchange — Part 2: Extensions	- (timeSpec)

ISO 20524-2:2020 Intelligent transport systems — Geographic Data Files (GDF) GDF5.1 — Part 2: Map data used in automated driving systems, Cooperative ITS, and multi-modal transport	- (timeSpec)
OGC Land and Infrastructure Conceptual Model Standard (LandInfra)	- (Surveying and representation subpackage)

ISO 19103 is utilized in Part 2 for CharacterString, Boolean, DateTime, Real and Integer classes, see Figure 1. Part 2, similar to Part 1, refers to ISO 19105 and ISO 19106 for profiling and testing the profile for compatibility with LADM. The general feature model of ISO 19109 has also been followed in the development of this part.

While LADM Edition I uses the 2003 version, LADM Edition II uses the 2019 version of the ISO 19107. One of the remarkable changes between these versions is that the definition of point is dropped from the last version; and ISO 19136-1:2020 became the authoritative source reference for point, which is defined as "*0-dimensional geometric primitive representing a position*" (ISO, 2020a). On the other hand, the class Point still included in ISO 19107:2019, see Figure 4. The class Point may look simple at first glance, but it is the start of a much larger part of the model where relevant LA functionality is available; including support for coordinate reference system (ISO, 2019a). The Point itself is an interface class that inherits from the Primitive interface class, which in turn inherits from Geometry interface class, see Figure 4. Of these three classes, only the interface class Point has an attribute of type (class) DirectPosition. It should be noted that that the Curve and Surface classes, as subclasses of the Orientable class, are also used in LADM to represent line and surface geometry, respectively.

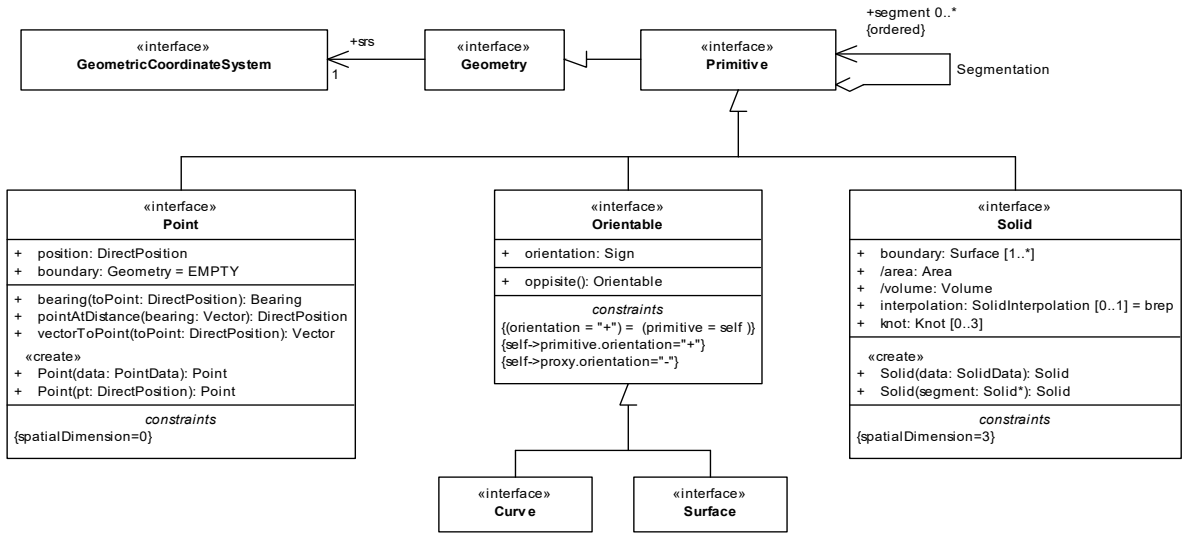

Figure 4. The Point, Curve and Surface geometries of ISO 19107 (ISO, 2019a)

ISO 19111:2019 Geographic information — Referencing by coordinates defines "*the conceptual schema for the description of referencing by coordinates.*" (ISO 2019a). The interface class CRS (Coordinate Reference System) has two specializations: the classes SingleCRS (again interface, with several interface subclasses, e.g., VerticalCRS, GeodeticCRS, DerivedCRS) and CompoundCRS (interface, an aggreagtion of SingleCRS);

see Figure 5. A SingleCRS is associated with one CoordinateSystem, which has in turn one or more CoordinateSystemAxis; see Figure 6. In summary, Point and CRS are part of a non-trivial model that should be able to provide all the functionality needed in the context of LADM (especially in the surveying and representation part): support for different coordinate systems and transformations.

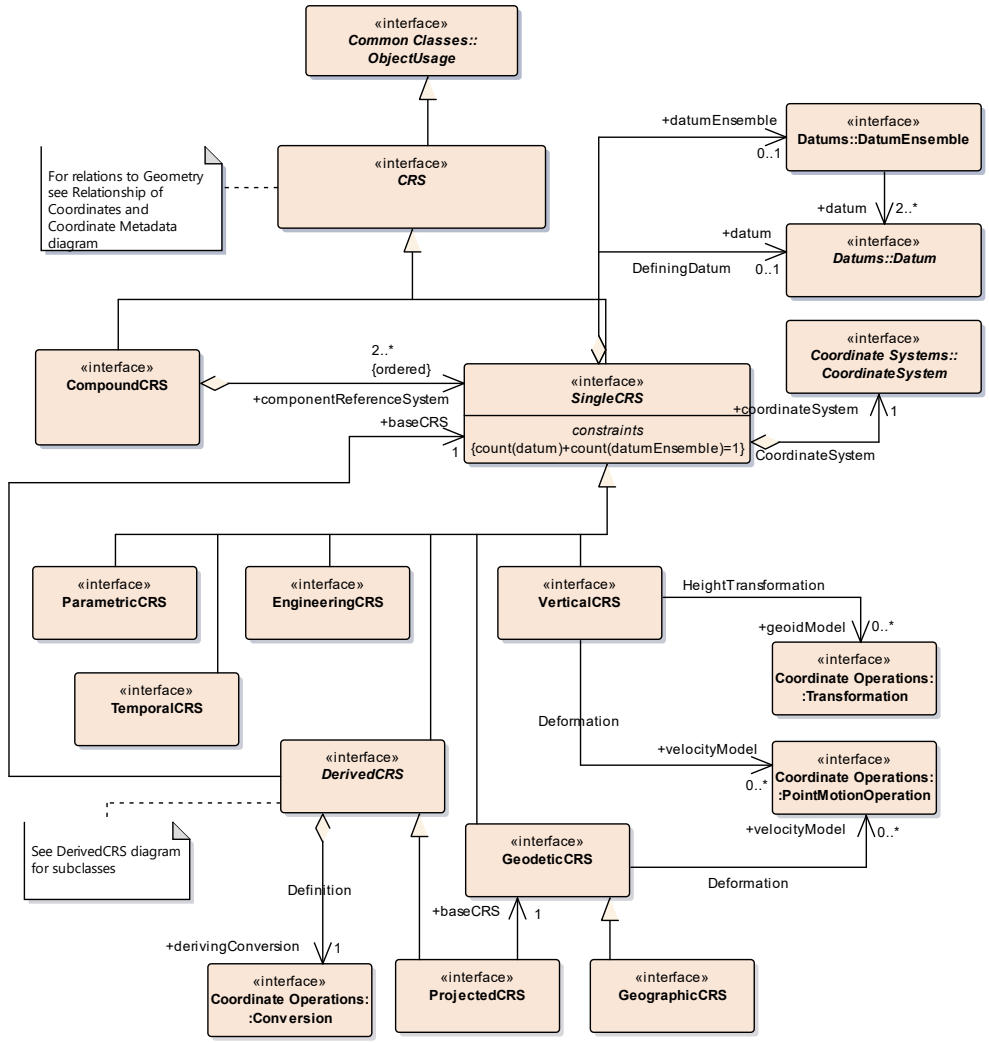

Figure 5. The class CRS (Coordinate Reference System) from ISO 19111 (ISO, 2019b)

The LI_Lineage class of ISO 19115-1 (ISO, 2014) used in the Part 2 data model to represent the lineage of the production method of a point instance. Figure 7 shows the LI_Lineage class and its associated classes (i.e., LI_ProcessStep, LI_Source and Abstract_LineageInformation) from ISO 19115-1 (ISO, 2014).

Another important ISO geographic information standard used in this document is ISO 19156, which defines "*a conceptual schema for observations, for features involved in the observation process, and for features involved in sampling when making observations*" (ISO, 2023b). The survey source data is modelled in Part 2 in LA_SurveySource which has the attribute

"procedure" is of type process and documents the actual survey procedure based on Procedure interface class of ISO 19156, see Figure 8 (ISO, 2023b).

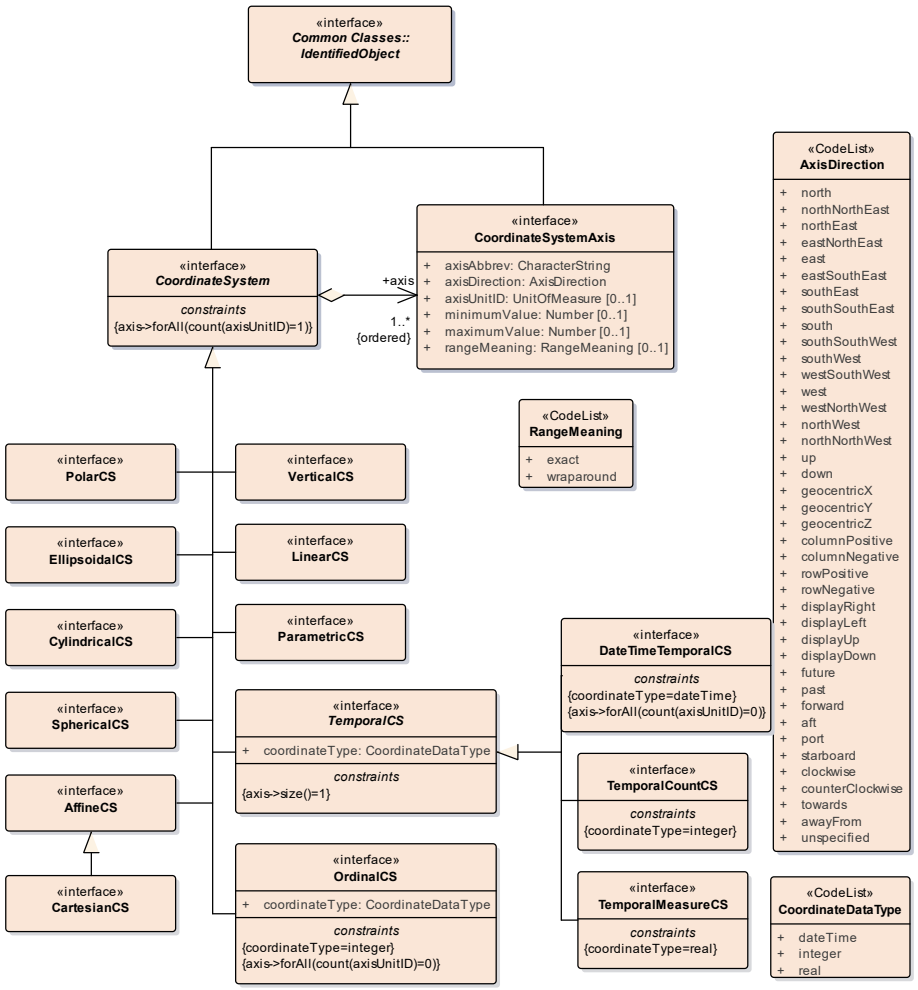

Figure 6. Coordinate system from ISO 19111 (ISO, 2019b)

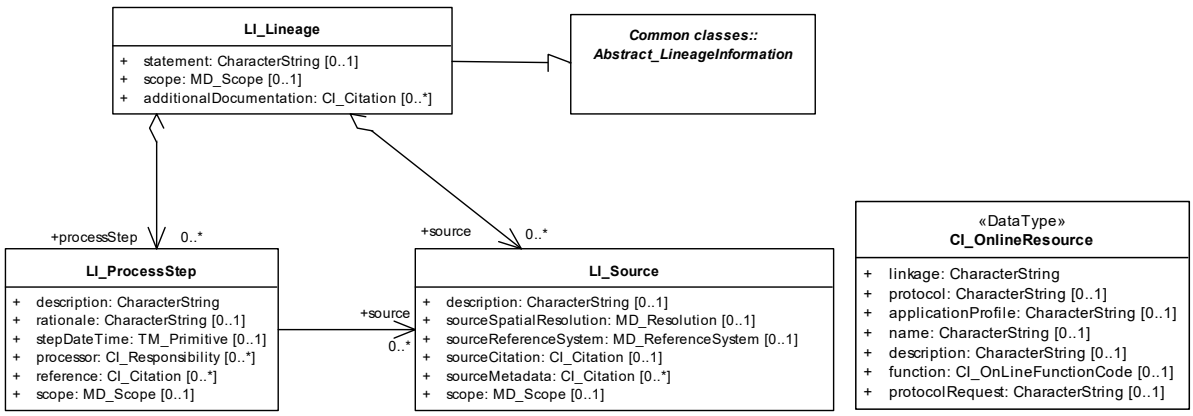

Figure 7. LI_Lineage (linked to Part 2) and CI_OnlineResource (linked to Part 3) classes from ISO 19115-1 (ISO, 2014)

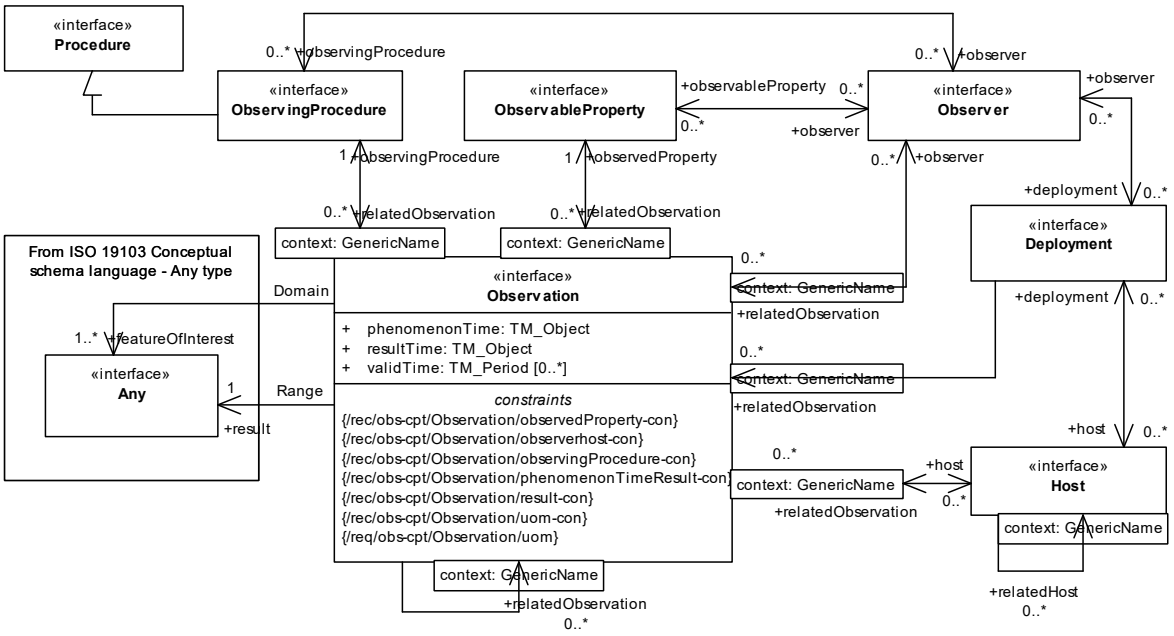

Figure 8. Observation from ISO 19156 (ISO, 2023b)

ISO 19157-1 utilized in Part 2 for representing absolute positional accuracy of a point instance. AbsolutePositionalAccuracy, which is a subclass of PositionalAccuracy, see Figure 9, is defined as "closeness of reported coordinate values to values accepted as true in a standard coordinate reference system" in the data model of ISO 19157-1 (ISO, 2023c).

The other standards that have been used in the development of Part 2 are those that have not been developed within ISO/TC 211. For example, *ISO 4217:2015 Codes for the representation of currencies* specifies "*the structure for a three-letter alphabetic code and an equivalent three-digit numeric code for the representation of currencies*" (ISO, 2015c). The amount attribute of the Part 2 LA_Mortgage class uses the codes specified in ISO 4217.

Supporting women's access to, use of and control over land in LADM Edition II, Part 2 is linked to *ISO/IEC 5218:2022 Information technology — Codes for the representation of human sexes* (Unger et al, 2021, 2023). This standard specifies "*a uniform representation of human sexes for the interchange of information*" (ISO/IEC, 2022). Part 2 creates a code list called LA_HumanSexesType, which includes the human sexes defined in ISO/IEC 5218: unknown, male, female and does not apply. It should also be noted that Part 2 is flexible enough to collect statistics on civil status and human sexes in support of UN SDG 5.

Attribute timeSpec of LA_RRR class of Part 2 is capable of handling other temporal descriptions, such as recurring patterns (every weekend, every summer, etc.). This means, for example, that a party can hold a right to use an apartment each year in March, or that a group of pastoralists has the right to cross a field each summer. In order to represent fuzzy time range specifications Part 2 is linked to *ISO 8601-2:2019 Date and time — Representations for information interchange — Part 2: Extensions* (ISO, 2019c) and *ISO 20524-2:2020*

Intelligent transport systems — Geographic Data Files (GDF) GDF5.1 — Part 2: Map data used in automated driving systems, Cooperative ITS, and multi-modal transport (ISO, 2020b).

Lastly, it should be mentioned that *OGC Land and Infrastructure Conceptual Model Standard* (LandInfra) (OGC, 2016) is used to refine the Surveying and Representation Subpackage of LADM Edition II Part 2, for details please see Kalogianni et al., (2021, 2023).

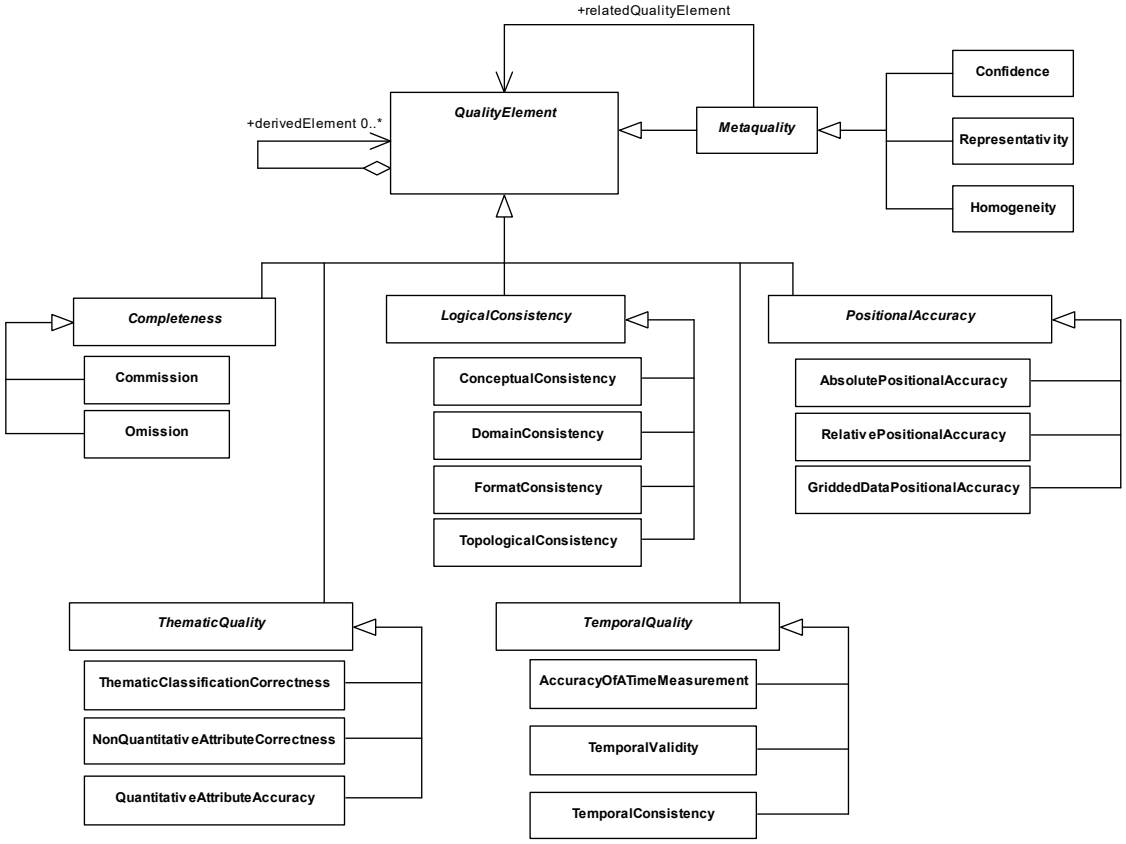

Figure 9. QualityElement from ISO 19157 (ISO 2023c)

LADM Edition II Part 2 contains annexes that present the relationships between this part of the standard and the other standards related to the land administration domain. Annex B of Part 2 mentions the Social Tenure Domain Model (STDM), which is a specialization of LADM (FIG/GLTN/UN-HABITAT, 2013). The LADM originated from areas with formal cadastral and land registration systems. It is noted that STDM includes most of the functionality of LADM, sometimes under different terminology. The normative Annex B reconciles the LADM class names with their aliases in STDM (ISO, 2012).

The informative Annex F presents the consistency between INSPIRE Data Specification on Cadastral Parcels (INSPIRE, 2014) and the LADM, by matching of concepts and compatible definitions of common concepts. To demonstrate compatibility, the LADM-based version of the INSPIRE cadastral parcels has been produced, explicitly showing how the INSPIRE development fits into the LADM and that there are no inconsistencies. (ISO, 2012).

Furthermore, the Annex K of Part 2 of LADM Edition II is established a link to OGC IndoorGML (OGC, 2019) to allow assigning rights, restrictions, and responsibilities to each indoor space to determine the accessible spaces for each type of party.

Finally, Annex L of Part 2 presents a case study for representing 3D legal spaces in buildings. This annex proposes terms and definitions refining 3D legal spaces in buildings based on the core concepts of LADM and Building Information Modelling (BIM) / Industry Foundation Class (IFC) (ISO, 2018) (Alattas et al., 2021).

2.3 LADM Edition II Part 3

LADM Edition II Part 3 Marine georegulation is a derived work, developed under a cooperative agreement with IHO based, on IHO standard S-121 and used with permission (ISO/DIS, 2023). The terms and definitions used in the development of LADM Edition II Part 3 are listed in Table 5.

Table 5. Terms and definitions used in LADM Edition II Part 3

Standard	Term	Definition of the term
ISO 19136-1:2020	Curve	1-dimensional geometric primitive, representing the continuous image of a line
IHO S-121 Maritime Limits and Boundaries (adopted)	Boundary	Delimitation between two or more zones
IHO S-121 Maritime Limits and Boundaries	Limit	Curve that defines a boundary or extent of a zone
IHO S-32 Hydrographic Dictionary	Marine	Relating to navigation or shipping or relating to or connected with the sea or used, or adopted for use at sea
IHO S-32 Hydrographic Dictionary	Maritime	Bordering on, or concerned with, or related to the sea

The standards and their relevant parts used in the development of the Part 3 data model are listed in Table 6. The standards in bold are the normative references in Part 3.

Table 6. Standards used in the LADM Edition II Part 3 data model and their relevant parts

Standard	Class
ISO 19152-1 Generic conceptual model	
ISO 19152-2 Land registration	
ISO 19103:2015 Geographic information — Conceptual schema language	DateTime, CharacterString, Integer, Boolean, Distance
ISO 19107:2019 Geographic information — Spatial schema	Geometry, Point, Orientable
ISO 19109:2015 Geographic information — Rules for application schema	- (General future model)
ISO 19110:2016 Geographic information — Methodology for feature cataloguing	- (Feature cataloguing)
ISO 19111:2019 Geographic information — Referencing by coordinates	CRS
ISO 19115-1:2014 Geographic information — Metadata — Part 1: Fundamentals	CI_Responsibility, CI_OnlineResource
ISO 19126:2021 Geographic information — Feature concept dictionaries and registers	- (Concept dictionary)
ISO 19131:2022 Geographic information — Data	- (Data production)

product specifications	
ISO 19135-1:2015 Geographic information — Procedures for item registration — Part 1: Fundamentals	- (Data registry)
ISO 19157-1:2023 Geographic information — Data quality — Part 1: General requirements	QualityElement

The normative references of Part 3 that are not mentioned in Part 1 and Part 2 are as follows: (a) *ISO 19110:2016 Geographic information — Methodology for feature cataloguing* defines "the methodology for cataloguing feature types (ISO, 2016), (b) *ISO 19126:2021 Geographic information — Feature concept dictionaries and registers* specifies "a schema for feature concept dictionaries to be established and managed as registers" (ISO, 2021), (c) *ISO 19131:2022 Geographic information — Data product specifications* describes "*requirements for the specification of geographic data products*" (ISO, 2022b), and (d) *ISO 19135-1:2015 Geographic information — Procedures for item registration — Part 1: Fundamentals* specifies "*procedures to be followed in establishing, maintaining, and publishing registers of unique, unambiguous, and permanent identifiers and meanings that are assigned to items of geographic information*" (ISO, 2015d).

According to the introduction section of ISO/DIS 19152-3 Marine georegulation (ISO/DIS, 2023), the International Hydrographic Organization (IHO)[1] supports standards development for oceanography, marine science and the UN SOLAS (UN, 1980) and UNCLOS (UN, 1982) conventions. IHO has developed a series of standards and specifications[2] that address the marine space. In particular the IHO standard S-121 on Maritime Limits and Boundaries (IHO, 2019). For their geographic information aspects, the IHO suite of hydrographic standards is based on the ISO ISO/TC 211 suite of Geographic Information standards, through the IHO Universal Hydrographic Data Model S-100 (IHO, 2018). The IHO S-121 standard on Maritime Limits and Boundaries directly supports the UNCLOS and is built upon the ISO 19152 LADM, more specifically LADM Edition II Part 3 is based on Part 1 and Part 2.

2.4 LADM Edition II Part 4

The LADM Edition II Part 4 Valuation information data model is based on the Part 1 and Part 2 data models. The terms and definitions from other standards and guidance documents used in the development of LADM Edition II Part 4 are listed in Table 7.

Table 7. Terms used from other standards and guidance documents in Part 4

Standard	Term	Definition of the term
ISO 6707-1:2020 Buildings and civil engineering works — Vocabulary — Part 1: General terms	Building	Construction works that is subject to a valuation that has the provision of shelter for its occupants or contents as one of its main purposes, usually partially or totally enclosed and designed to stand permanently in one place
OGC Land and Infrastructure Conceptual Model	Accessory part	Privately owned building part, generally attached to one or more condominium unit
	Condominium	Concurrent ownership of real property that has been divided

[1] International Hydrographic Organization: https://iho.int/
[2] IHO Standards, Specifications and Regulations: https://iho.int/en/standards-and-specifications

Standard (LandInfra)	unit	into private and common portions, and the privately owned part is made up of clearly demarcated parts of a building
UNECE Land Administration Guidelines with special reference to countries in transition	Market value	The most probable sale price of a real estate property in terms of money, assuming a competitive and open market
UNECE Land Administration in the UNECE Region: development trends and main principles	Sales comparison approach	Valuation of property based on estimates of the worth of similar properties
	Income approach	Valuation of property on the basis of its income stream
	Cost approach	Valuation of property based on estimates of costs
IAAO Standard on Mass Appraisal of Real Property	Mass appraisal	Process of valuing a group of properties as of a given date, using standard methods, employing common data, and allowing for statistical testing

The standards and their relevant parts used in the development of the Part 4 data model are listed in Table 8. The standards in bold are the normative references in Part 4.

Table 8. Standards used in the LADM Edition II Part 4 data model and their relevant parts

Standard	**Class**
ISO 19152-1 Generic conceptual model	
ISO 19152-2 Land registration	
ISO 19103:2015 Geographic information — Conceptual schema language	DateTime, CharacterString, Boolean, Integer, Decimal, Area, Volume
ISO 19105:2022 Geographic information — Conformance and testing	- (Abstract test suite)
ISO 19106:2004 Geographic information — Profiles	- (Abstract test suite)
ISO 19109:2015 Geographic information — Rules for application schema	- (General future model)
ISO 4217:2015 Codes for the representation of currencies	Currency
ISO 9836:2017 Performance standards in building — Definition and calculation of area and space indicators	- (Building area and volume types)
International Property Measurement Standards (IPMS): All buildings	- (Building area and volume types)
OGC Land and Infrastructure Conceptual Model Standard (LandInfra)	- (Condominium unit and condominium building)

The references of Part 4 that are not mentioned in Part 1, Part 2 and Part 3 are as follows: *ISO 9836:2017 Performance standards in building — Definition and calculation of area and space indicators* specifies "*the definition and calculation of surface area and volume indicators*" (ISO, 2017). Similarly, International Property Measurement Standards (IPMS): All buildings (IPMSC, 2023) provides "*the foundation for incorporation into and adoption of building measurement conventions in global jurisdiction*[3]". These standards are used to structure VM_BuildingAreaType and VM_BuildingVolumeType code lists. The OGC Land and Infrastructure Conceptual Model Standard (LandInfra) (OGC, 2016) is utilized to model

[3] The International Property Measurement Standard (IPMS) https://ipmsc.org/

condominium unit and building parts of the data model of Part 4. Finally, it should also be noted that numerous terms and definitions at attribute level and code list value level, which may be changed/revised during the project team meetings, are adapted from international valuation standards during the development of Part 4, for more detailed information see Çağdaş et al. (2017).

2.5 LADM Edition II Part 5

The LADM Edition II Part 5 Spatial plan information data model is based on the Part 1 and Part 2 data models. The standards, terms and definitions used in the development of LADM Edition II Part 5 are listed in Table 9.

Table 9. Terms used from other documents in LADM Edition II Part 5

Standard	Term	Definition of the term
INSPIRE Planned Land Use	Spatial plan	A set of documents that indicates a strategic direction for the development of a given geographic area, states the policies, priorities, programmes and land allocations that will implement the strategic direction and influences the distribution of people and activities in spaces of various scales
European Commission	spatial planning	Methods used largely by the public sector to influence the future distribution of activities in space

The standards and their relevant parts used in the development of the Part 5 data model are listed in Table 10. The standards in bold are the normative references in Part 5.

Table 10. Standards used in the LADM Edition II Part 5 data model and their relevant parts

Standard	Class
ISO 19152-1 Generic conceptual model	
ISO 19152-2 Land registration	
ISO 19103:2015 Geographic information — Conceptual schema language	DateTime, CharacterString, Integer, Area, Volume,
ISO 19105:2022 Geographic information — Conformance and testing	- (Abstract test suite)
ISO 19106:2004 Geographic information — Profiles	- (Abstract test suite)
ISO 19107:2019 Geographic information — Spatial schema	Point
ISO 19109:2015 Geographic information — Rules for application schema	- (General future model)

Part 5 is developed/influenced by the Plan4all project which was initiated to focus on the harmonization of spatial planning data based on the best practices in EU member countries for seven themes (i.e., land cover; land use; utility and government services; production and industrial facilities; agricultural and aquaculture facilities; area management/restriction/ regulation zones, and reporting units; natural risk zones) (Cerba, 2010). The Part 5 may promote interoperability through the integration of outputs of spatial planning processes with land registry and cadastre.

3. LADM AND INTERNATIONAL GUIDELINES AND FRAMEWORKS

LADM Edition I is based on the principles of Cadastre 2014 (Kaufmann and Steudler, 1998; Steudler 2014), and a number of standards, in particular those published by ISO/TC 211 and, of course, other committees. Since LADM Edition II is designed as backwards compatible with LADM Edition I, LADM Edition II is also based on the principles of Cadastre 2014. It should be noted that the principle of legal independence from Cadastre 2014 can be implemented with complete separate LADM implementations of Cadastre 2014 per layer or with only the spatial unit package of LADM per layer.

Both LADM Edition I and LADM Edition II are based on the continuum of land tenure/rights principle as specified in the Secure Land Rights for All (UN-HABITAT, 2008) and assessed in the Framework for Evaluating Continuum of Land Rights Scenarios (UN-HABITAT/GLTN, 2016). The former one argues that "*policymakers should adopt and implement the continuum of land rights because, no single form of tenure can meet the different needs of all social groups. However, a range of land tenure options enables both women and men from all social groups to meet their changing needs over time*." The latter one describes the continuum of land rights as "*a situation (a continuum of land rights scenario) where, in a particular country, region or area, different tenure forms incorporating a range of interests exist simultaneously*" and provides a framework for evaluating land in continuum of land rights scenario. The first requirement of LADM Edition II Part 2 is about the continuum of land rights and it reads as follows: "*The Triple Object (Spatial Unit) – Right (RRR) – Subject (Party) shall be the common pattern and the basic structure for LA. Groupings of objects or subjects should be supported. The flexibility of LA model should be based on the recognition that people's land relationships appear in many different ways, depending on local tradition, culture, religion and behaviour*." It should be mentioned that a quite similar requirement is also followed in developing LADM Edition I, see Lemmen et al. (2015).

After publication of LADM Edition I, it has been implemented by various organizations. GLTN developed STDM, which is a specialization of LADM, and STDM software[4]. IHO developed S-121 based on LADM. On the other hand, the terms specified by the IPMS: All Buildings standard (IPMSC, 2023) are used to represent building floor areas in LADM Edition II. Similar approaches can be followed to implement guidance documents and frameworks. This, of course, fits very well into the context of the implementation of the Sustainable Development Goals (SDGs). With the recent advancements represented by LADM Edition II, which includes critical components such as land value, land use and marine geo-regulation, the model has the potential to support multiple SDGs. It aligns with SDGs 1 (no poverty), 2 (zero hunger), 5 (gender equality), 8 (decent work and economic growth), 9 (industry, innovation and infrastructure), 11 (sustainable cities and communities), 14 (life below water) and 15 (life on land), as assessed by ISO/TC 211. In addition, Land Parcels are determined as one of the 14 global fundamental geospatial data themes by UN-GGIM (UN-GGIM, 2019). According to this data theme, land parcels are a powerful governmental tool to achieve many SDGs, including 1.4, 2.4, 8, and 11.1 (UN-GGIM, 2019). It should be noted that UNGGIM Land Parcels data theme recognizes ISO 19152:2012 LADM as existing

[4] Social Tenure Domain Model: https://stdm.gltn.net/

geospatial data standards on land parcels together with INSPIRE Data Specification on Cadastral Parcels (INSPIRE, 2014) and International Land Measurement Standard (ILMS) (ILMSC, 2019).

LADM Edition II can also be utilized to implement various clauses of the New Urban Agenda (UN, 2016), such as:

- "*… The use of digital platforms and tools, including geospatial information systems, will be encouraged to improve long-term integrated urban and territorial planning and design, land administration and management, and access to urban and metropolitan services*." (cf. Clause 156),
- "*We will promote compliance with legal requirements through strong, inclusive management frameworks and accountable institutions that deal with land registration and governance, applying transparent and sustainable management and use of land, property registration and sound financial systems. We will support local governments and relevant stakeholders, through a variety of mechanisms, in developing and using basic land inventory information, such as cadastres, valuation and risk maps, and land and housing price records, to generate the high-quality, timely and reliable data — disaggregated by income, sex, age, race, ethnicity, migration status, disability, geographic location and other characteristics relevant in the national context — needed to assess changes in land values, while ensuring that these data will not be used for discriminatory land-use policies.*" (cf. Clause 104),
- "*We will support appropriate policies and capacities that enable subnational and local governments to register and expand their potential revenue base, for example, through multipurpose cadastres, local taxes, fees and service charges, in line with national policies, while ensuring that women and girls, children and youth, older persons, persons with disabilities, indigenous peoples and local communities, and poor households are not disproportionately affected*." (cf. Clause 134)
- "*We will support science, research and innovation, including a focus on social, technological, digital and nature-based innovation, robust science-policy interfaces in urban and territorial planning and policy formulation and institutionalized mechanisms for sharing and exchanging information, knowledge and expertise, including the collection, analysis, standardization and dissemination of geographically based, community-collected, high-quality, timely and reliable data disaggregated by income, sex, age, race, ethnicity, migration status, disability, geographic location and other characteristics relevant in national, subnational and local contexts*." (cf. Clause 157)

The Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security (VGGT) (FAO, 2012) set out "*principles and internationally accepted standards of responsible practices for the use and control of land, fisheries and forests. They provide guidance for improving the policy, legal and organizational frameworks that regulate tenure rights; for enhancing the transparency and*

administration of tenure systems.[5]" The implementation of various clauses in VGGT can be achieved through the LADM compatible profiles, such as:

- "*States should provide systems (such as registration, cadastre and licensing systems) to record individual and collective tenure rights in order to improve security of tenure rights, including those held by the State and public sector, private sector, and indigenous peoples and other communities with customary tenure systems*" (Clause 17.1).
- "*States should ensure that appropriate systems are used for the fair and timely valuation of tenure rights for specific purposes, such as operation of markets, security for loans, transactions in tenure rights as a result of investments, expropriation and taxation. Such systems should promote broader social, economic, environmental and sustainable development objectives*." (Clause 18.1).
- "*Regulated spatial planning affects tenure rights by legally constraining their use. States should conduct regulated spatial planning, and monitor and enforce compliance with those plans, including balanced and sustainable territorial development, in a way that promotes the objectives of these Guidelines. In this regard, spatial planning should reconcile and harmonize different objectives of the use of land, fisheries and forests*." (Clause 20.1).

The relevant parts of LADM can also be used to implement Fit-For-Purpose Land Administration (FFPLA) principles (FIG/World Bank, 2013), such as:

- "*General boundaries rather than fixed boundaries*" (LADM supports both approaches),
- "*Aerial imageries rather than field surveys*" (LADM supports both approaches),

It is worth noting that the FFPLA (FIG/World Bank, 2013) refers to LADM and STDM as follows: "*The STDM is a sub-version of the new ISO standard on Land Administration Domain Model (ISO 19152, 2012) that presents a generic and inclusive solution as a way forward for building flexible land administration systems*." In addition, Fit-for-Purpose Land Administration: Guiding principles for country implementation (UNHabitat/GLTN/Kadaster, 2016) also refers to LADM as follows: "*In order to assure an easy and adaptable interoperability layer with other stakeholders, the data model chosen for the FFP Land Administration system should be based on (ISO 19152:2012) - Land Administration Domain Model (LADM) and the derived Social Tenure Domain Model (STDM)*.

Another document that referred to LADM is the UN-GGIM Expert Group on Land Administration and Management's Framework for Effective Land Administration A reference for developing, reforming, renewing, strengthening or modernizing land administration and management systems (UN-GGIM, 2020). This framework specifies a number of qualities (e.g., (a) "*land data and land processes should be appropriate, accessible, affordable and integratable with other data organized under the UN Global Fundamental Geospatial Data Themes*", (b) "*land data may be gathered from a wide range of sources, scales and sensors - but, in all cases, should generally deliver its metadata and enable standardized identification*

[5] Responsible Governance of Tenure: https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/416990/

of the spatial extent, time period, and people to which the right, restriction or responsibility pertains to" and (c) "*Availability, accessibility, and interoperability of the land data are*" required) that are necessities for effective land administration. According to this framework, LADM and IHO S-121 provide starting points for creating these qualities (UN-GGIM, 2020). Furthermore, STDM is also recognized in this framework: "*The Land Administration Domain Model (ISO 19152) provides an ISO endorsed data model whereas the Social Tenure Domain Model (STDM), in Annex I of the LADM, provides a concept and data model to record all people to land relationships. ISO/TC211 is working on the second edition of LADM. The IHO S-121 standard focuses on maritime limits and boundaries.*"

LADM is also cited in the Addis Ababa Declaration Geospatial Information Management Towards Good Land Governance for the 2030 Agenda as follows: "develop and agree on a set of fundamental geospatial information elements for land governance as a subset of the UN-GGIM fundamental data themes aligned with the SDG global indicator framework, taking into account the ISO 19152 Land Administration Domain Model and progress in multi-dimensional cadastre and city models" (UN-GGIM, 2016).

Finally, the ILMS is a framework to enable the reporting process of due diligence (meaning an assessment that is considered reasonable and practicable in the environment in which the ILMS instruction is being carried out) on land and property matters for people and legal entities (ILMSC, 2019). The definition section of the ILMS defines the LADM, but it is not cited in the main text. Kavanagh et al. (2021) state that ILMS and LADM can feed into each other and can be integrated.

4. CONCLUSION

Sustainable and interoperable data management requires the use of existing standards wherever possible. LADM Edition II has been developed with this principle in mind. It is linked not only to ISO/TC 211 standards, but also to standards published by other ISO committees, as well as OGC, IFC/BIM, IHO and so on. It should be noted that since no part of LADM Edition II is now an international standard, the linked standards may be subject to change.

The purpose of this paper is to document which standards LADM Edition II is based on and associated with, and which guidelines and frameworks are in some way related to LADM. A brief description of the standards and their relevant definitions and classes that have been used in the development of the first five parts of LADM Edition II is organized in this paper. It is clear that the LADM data model is not only based on many standards, but also references and can be used to implement many guidelines and frameworks on land administration.

It is expected that LADM Edition II Part 6 will also be based on several different standards as one of its focuses is on LA processes. It is anticipated that Part 6 may include detailed information on the integration/implementation of IPMS and ILMS with LADM as they include processes for area measurement and reporting, respectively.

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BIOGRAPHICAL NOTES

Abdullah Kara holds a Ph.D. degree from Yıldız Technical University (YTU) with a thesis on the extension of Land Administration Domain Model (LADM) with valuation information, which is used as a basis for the development of LADM Part 4 - Valuation information. He is currently working as a post-doctoral researcher at the GIS Technology Section, Delft University of Technology. He has been actively involved in FIG working groups.

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