

## Requirements Based Design of the LADM Edition II

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**DOI**

[10.4233/uuid:8843a8e1-09b0-4b44-afaf-73b391e26e8e](https://doi.org/10.4233/uuid:8843a8e1-09b0-4b44-afaf-73b391e26e8e)

**Publication date**

2023

**Document Version**

Final published version

**Published in**

11th International FIG Workshop on the Land Administration Domain Model & 3D Land Administration (LADM2023)

**Citation (APA)**

Kara, A., Lemmen, C., Kalogianni, E., & van Oosterom, P. J. M. (2023). Requirements Based Design of the LADM Edition II. In P. van Oosterom, & J. M. Paasch (Eds.), *11th International FIG Workshop on the Land Administration Domain Model & 3D Land Administration (LADM2023)* (pp. 181-194). International Federation of Surveyors (FIG). <https://doi.org/10.4233/uuid:8843a8e1-09b0-4b44-afaf-73b391e26e8e>

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# Requirements Based Design of the LADM Edition II

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**Key words:** LADM, ISO, 3D

## SUMMARY

This paper examines the requirements based design of the LADM Edition II. The requirements are the starting point for the Abstract Test Suite (ATS, Annex A in an ISO standard). The requirements/ATS can be used to assess if a given LADM country profile with a specific application schema is conformant with the LADM standard. The requirements are a new aspect of ISO standards and this offers several benefits:

1. requirements express explicitly the needs from experts in the domain,
2. requirements are a very concise manner to describe the content of the standard,
3. requirements are used to introduce of the actual standard content (in the case of LADM, part of the UML class diagram), and as mentioned above,
4. requirements form the basis of the ATS.

This paper describes the new structure of the second edition of the standard and the capabilities of this new edition, which is organized in multiple Parts (standards addressing a specific part of the scope) and Packages (groups of conceptually closely related classes, i.e. with relative high number of associations between the classes from one package compared to the number of cross package associations), with a particular attention to the requirements and design related decisions taken in the revision process.

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## 1. INTRODUCTION

The Land Administration Guidelines by the United Nations Economic Commission for Europe (UNECE) include a 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*”. Land is defined in the LADM Edition II as the “*spatial extent to be covered by rights, restrictions and responsibilities and encompass the wet and dry parts of the Earth surface, including all space above and below*”. Inclusion of the marine georegulation, land value information, as well as spatial plan information in LADM is well aligned to those definitions. From these definitions it can be seen that LA is a broad field with several functions, as introduced by Enemark (2006). In all these functions the 3D representations play an important role.

The Edition I of the Land Administration Domain Model (LADM) is published by ISO as an International Standard (IS) in 2012. It provides a shared ontology, defining a common terminology for land administration (Lemmen et al., 2015). The Edition I includes both support for 3D representations of spatial units and a seamless integration of 2D and 3D spatial units (Lemmen et al., 2010). The 3D capabilities of LADM have been used and reported in a range of publications, from visualizing and querying 3D properties through a 3D platform, to BIM-based applications for 3D LA and 3D property valuation (Ying et al., 2011, Karki et al., 2011, Jeong et al., 2012, Felus et al., 2014, Zulkifli et al., 2015, Dimopoulou et al., 2017, Shnaidman et al., 2019b, Kalogianni et al., 2020, Alattas et al., 2021).

Although the LADM Edition I is extensively used (Kalogianni et al., 2021) and is applicable for various use cases and purposes, ISO rules prescribe periodic review. This started with a meeting of the UN-GGIM Expert Group on Land Administration and Management that was held in 2017, in Delft, The Netherlands. It was concluded that a revision of the LADM Edition I is required in order to provide better tools in support to tenure security with better coverage of LA (UN-GGIM, 2019). As a result of the voting on the systematic review of ISO 19152:2012 (March 2018) it became clear that the majority of the ISO/TC 211 P-members expressed their wish for the revision. Therefore, the ISO Stage 0 project started in May 2018 during the 46<sup>th</sup> Plenary Meeting Week of ISO/TC 211 in Copenhagen, Denmark.

In order to revise LADM Edition I, several FIG LADM Workshops were organized, where options for improvement and extensions were discussed among experts; see further inputs (needs) for Edition II in FIG (2018), Lemmen et al. (2019) and Lemmen et al. (2020). In the 48<sup>th</sup> Plenary Meeting Week of ISO/TC 211 (June 2019), Standards Council of Canada (SCC)

proposed LADM Edition II as multi-part. The following structure for the multi-part option (as multiple coherent packages with every part in separate standard) has been agreed:

- Part 1 – Generic conceptual model
- Part 2 – Land registration
- Part 3 – Marine georegulation
- Part 4 – Valuation information
- Part 5 – Spatial plan information
- Part 6 – Implementation aspects

The Parts 1, 2, 4 and 5 are the Parts in which the authors are currently involved. Part 1 will be a high-level umbrella standard; Part 2 is largely based on LADM Edition I and focuses on land registration, with an enhanced support of surveying functionality, including new subclasses of spatial unit, and extended 3D spatial profiles. Part 3 harmonizes the description of rights, restrictions and responsibilities (RRRs) and aligns land concepts with marine aspects from the marine domain based on IHO S-121 Maritime Limits and Boundaries Product Specification. Part 4 concerns valuation information in the context of land administration, while Part 5 deals with spatial planning information and includes the planned use of the land (zoning), resulting in RRRs. Lastly, Part 6 is planned to be about implementation of the LADM and will be developed in close collaboration with OGC.

The methodology used in the revision of the LADM is the Design Research Methodology, which is consistent with the ISO methodology for the development of standards. To mention the main steps of the ISO methodology, starting with the fact that standards should contain a set of requirements that form the basis for the scope of the standard and are further used to specify an abstract test suite. In addition, the code list values of each class of the standard should have a description and, where appropriate, references to the source of these definitions should be added. These ISO steps were not followed in the development of LADM Edition I and therefore directly impact the design and structure of all parts of Edition II.

The remainder of the paper is organized as follows: Section 2 presents the needed for requirements in ISO standards and the approach we followed. Section 3 then presents the requirements and package structure of LADM Edition II. A reflection on the decisions made during the requirement-based design of LADM Edition II is given in Section 4, together with the conclusion.

## **2. REQUIREMENTS IN ISO STANDARDS**

Within ISO the use of requirements has become obligatory quite recently. Initially the editors were not that enthusiastic about adding one more task to the revision job(s). However, when implementing the opinion changed and the importance of the requirements was recognized and even highly appreciated. Actually, in the PhD thesis of Lemmen (2012), the basis of LADM Edition 1, requirements were already introduced. However, they were kept outside the standard itself. So, this thesis was the starting point for the requirements in parts 1 and 2. For requirements in parts 3, 4, and 5, experts from the various domains were consulted:

hydrography (via the IHO), valuation (via FIG comm.9 and RICS) and spatial planning (via FIG comm. 8).

In Edition 1 of LADM and in the first WDs of Edition 2 the requirements were not included. In the fall of 2022, the requirements have been first introduced in the various versions (CD, DIS) of the various parts (1 to 5). In the first half of 2023 balloting and commenting of the various parts have been received and processed. This resulted in a second set of more refined requirements, which are presented in the next section. In the first attempt there were some flaws:

- complex requirements, actually consisting of multiple requirements,
- partly overlap in constraints, just different wording, but same intention,
- missing constraints, part of the LADM Edition 2 not covered by requirements,
- wrong wording, as ISO typically require requirements to use 'must' or 'shall' and not lighter verbs.

### 3. SPECIFICATION OF THE REQUIREMENTS

The LA paradigm with the different functions, land tenure, value, use and development has been around for years (see UNECE, 1996; Enemark, 2006), but there was not a detailed model to support the refinement, development and implementation of LA functions. LADM Edition I was mainly focusing on land tenure. In this context, LADM Edition II aims to fill this gap by extending the scope of the first Edition with land value, use and development. This paper describes the harmonization of requirements distilled from the comments of the ISO TC/211 member states, the workshops and other meetings and sources (see below) and grouping them as basis for the different parts of LADM Edition II..

The distilled requirements used to design the packages are shown in the Tables 1 to 5. The requirements specified in Part 1 apply also to the other parts (i.e., Parts 2, 3, 4 and 5) as they are all based on the definitions of Part 1. It should be noted that Part 1 has been submitted for FDIS stage while Part 2, Part 4 and Part 5 will be submitted for DIS stage before the end of 2023. Therefore, the requirements may change over time during the voting and commenting rounds. The requirements in the tables are colored using the colors shown in Figure 1 to indicate the various packages. As far as the coloring of the table and Figure 1 is concerned, green has been chosen for the Party package, yellow and blue for the Administrative and Spatial Unit packages respectively, and light pink for the Survey and Representation sub-package (as in the earlier LADM publications). For the parts introduced in Edition II, different colors are used; the packages of Part 3 are colored grey, while Part 4 and Part 5 are colored orange and light blue respectively. Some requirements have been label generic and these are 'colored' white, this mainly applies to the requirements in Part1, but there are also some generic requirements in Part 2.

Most requirements in Table 1 and Table 2 are based on Lemmen (2012), ISO (2012) and Lemmen et al. (2015), but refined in the ISO standardization process during the development of LADM Edition II, Parts 1 and 2.

**Table 1.** The proposed requirements for LADM Edition II Part 1

<b>Requirement name / Solution</b>	<b>Requirement Description</b>
Requirement 1-1 'Core Class Conformant'	<b>LADM-based systems can be designed based on core LADM classes.</b> The description, development and refinement of efficient and effective land administration/georegulation systems using this part of ISO 19152 shall be compatible with the classes described in Clause 5 (Party, Administrative and Spatial Unit Packages), and the classes and attributes described in Clause 6 (LA_Source and VersionedObject).
Requirement 1-2 'Triplet Structure Present'	<b>All people-to-land relationships can be managed</b> The three, possible compound, elements 1. LA_Party – 2. LA_RRR and/or LA_AdministrativeSource <sup>1</sup> – 3. LA_BAUnit/ LA_SpatialUnit provide the common pattern for land administration/georegulation and form the basic structure. A land administration/georegulation system shall be constructed using groupings of LA_SpatialUnit, LA_BAUnit and/or LA_Party classes.
Requirement 1-3 'Backwards Compatible'	<b>Compatibility between the versions</b> Any country profile established using the elements defined in conformance with ISO 19152:2012 shall remain conformant with this version of the standard <sup>2</sup> .
Requirement 1-4 'Versioned Objects'	<b>Maintenance of history should be supported</b> All land administration/georegulation systems shall support (bi-) temporal data management by inheritance from LA_VersionedObject.
Requirement 1-5 'Oid Present'	<b>All subjects, sources, objects etc. can be identified</b> The local object identifier (Oid) shall be unique within the namespace.
Requirement 1-6 'Source Document Present'	<b>Reference to source documents should be supported</b> All land administration/georegulation systems shall make use of the LA_Source class to support references to source documents.

The first eight requirements in Table 2 are not colored, as they are general requirements that apply to all packages in Part 2.

**Table 2.** The proposed requirements for LADM Edition II Part 2

<b>Requirement name / Solution</b>	<b>Requirement Description</b>
Requirement 2-1 'Based on General Conceptual Model'	<b>All requirements in Part 1 apply to Part 2</b> This part of the standard is based on Part 1 – General Conceptual Model. All requirements contained in 19152-1 shall apply to this part of the standard.
Requirement 2-2 'Continuum of Rights'	<b>All rights should be specified in a seamless way, not only real rights, also customary and personal rights.</b> The Continuum of Land Rights shall be supported. This includes the recognising, recording, administering a variety of appropriate and legitimate land tenure forms, such as

<sup>1</sup> In some jurisdictions, deeds registries only record deeds/administrative sources. They do not have records of RRRs. Also, in some common law jurisdictions, transactions may refer to a survey plan/spatial source (and not a parcel number/spatial unit). The relationship between the party and the spatial unit is established by a legal instrument (source).

<sup>2</sup> This implies that also normative references as used in ISO 19152:2012 are also used in 19152-1 or updated versions of the reference (i.e., ISO 19103, ISO 19105, ISO 19107 and ISO 19109).

	registered freehold, lease, group tenure, adverse possession, occupancy, customary.
Requirement 2-3 'Grouping People Land'	<b>Grouping people and land</b> Groupings of people and land shall be supported. The flexibility of LA model can be based on the recognition that people to land relationships appear in many different ways, depending on local tradition, culture, religion and behaviour.
Requirement 2-4 'Different Organisations'	<b>Distributed environment</b> Land administration data can be maintained by different organisations. And within one organisation at many sites. Administrative territories for organisations can be completely different. The LADM based systems shall be implemented as a distributed set of (geo-) information systems, each supporting the maintenance processes (transactions in land rights, establishment of rights, restrictions and responsibilities) and the information supply of parts of the data set, represented in this model.
Requirement 2-5 'Keep Data to Source'	<b>No duplications unless something has different meanings in different models (roles)</b> Land administration data shall be kept to the source within Spatial Data Infrastructure (SDI). Today all data (spatial and thematic) can be stored in a Data Base Management System (DBMS). Information products are becoming flexible combinations of digital data components and additional facilities and services. This can replace the exchange of copies of data sets between organisations. Multi source information products require avoidance of redundancy and good standardisation protocols.
Requirement 2-6 'Authentic Source Documents'	<b>Continuous source updates maintenance; see also Requirement 1-6</b> Inclusion of new data and data updates shall be documented. This concerns legal administrative data, spatial data and/or technical data.
Requirement 2-7 'Transparency'	<b>Transparency in history management and updates</b> All updates shall be traceable in LADM compliant LASs
Requirement 2-8 'Responsible Person'	<b>Responsible person should be part of source data</b> The names of persons responsible for transactions shall be part of the source data set (conveyors, surveyors, registrars, etc.). This is one reason for management of history and for documentation of all updates.
Requirement 2-9 'Continuum of Right Parties'	<b>All right holders should be clearly identified</b> Efficient and effective LAS using this part of ISO 19152 LADM shall support all types of parties. Parties can be persons, or groups of persons, or non-natural persons, that compose an identifiable single entity. A non-natural person may be a tribe, a family, a village, a company, a municipality, the state, a farmer's community/co-operation, a slum dwellers group/organisation, a religious community, and so on. This list may be extended, and it can be adapted to local situations, based on community needs.
Requirement 2-10 'Basic Administrative Unit'	<b>Spatial units that have the same right should be grouped together</b> In combination to the Triple (1. LA_Party – 2. LA_RRR and/or LA_AdministrativeSource – 3. LA_BAUnit/LA_SpatialUnit) the constellation of basic administrative units shall be supported. The purpose of a baunit is the grouping of spatial units, which have the same rights, etc. attached. A baunit can play the role of a party: a baunit may be owned by one or more other baunits.
Requirement 2-11 'Shares In RRR'	<b>Shares in right should be supported</b> Holding shares in rights, restrictions, responsibilities shall be supported.
Requirement 2-12 'Continuum of Spatial Units'	<b>All spatial units should be specified in a seamless way</b> Representation of a broad range of spatial units, with a clear quality indication, shall be supported by an LADM compliant LAS. Spatial units are the areas of land (or water – e.g., water rights and the marine environment) where the rights and social tenure relationships apply. Spatial units can be represented as a text ("from this tree to that river"), as a sketch, as a single point, as a set of unstructured lines, as a surface, or as a 3D volume.
Requirement 2-13 'Spatial Unit Identifiers'	<b>All spatial units should have a unique identifier</b> Spatial units shall have a unique identifier. A key component in LASs is the spatial unit identifier, the parcel identifier or the unique parcel reference number. This acts as a link between the parcel itself and all record related to it. It facilitates data input and data exchange. There can be a need to change identifiers during data collection.

Requirement 2-14 'Spatial Source Based Maps'	<b>Cadastral maps should be based on surveys</b> Cadastral maps shall be based on spatial sources, such as surveys, design sources, topographic maps, etc.
Requirement 2-15 'Data Acquisition Methods'	<b>Different data acquisition methods can be used to identify boundaries of spatial unit</b> Surveying of boundaries shall be supported. Surveys may concern the identification of boundaries of spatial units on a photograph, an image, or a topographic map. Surveys can be conventional land surveys, based on hand-held GPS. In all cases the representation of 'legal' reality is differentiated from the 'physical' reality. There may be sketch maps drawn up locally. Depending on the local situation, different registrations or recordings of land rights are possible.
Requirement 2-16 'Cadastral Reference System'	<b>Cadastral surveys should be represented in a reference system</b> Efficient LASs compliant with this part of LADM shall be capable of producing co-ordinates, forming an essential component of cadastral systems. Provisions may be made to accommodate future changes in the reference system that may occur as a result of technical improvements. These may affect all co-ordinate-based systems. Imagery can be used depending on the user requirements, cost, and timing among other factors. It can be possible to include all documentation on data collected as evidence from the field.
Requirement 2-17 'Data Quality'	<b>Quality of cadastral data should be specified</b> The cadastral information shall be as complete as possible, reliable (which means ready when required), and rapidly accessible. Users of cadastral information need clarity, simplicity and speed in the registration process. Consistency between spatial and legal administrative data is important. Topology integrated with geometry and other attributes is relevant. The system must be ready to keep the information up to date. Data quality of spatial data may be improved in a later stage of development of a LAS, this has to be documented. For combined data products from different sources the quality descriptions and meta data related to the original data are relevant in relation to liability and information assurance.

Table 3. The proposed requirement for LADM Edition II Part 4

Requirement name / Solution	Requirement Description
Requirement 4-1 'Core LADM Conformant'	<b>A land administration system specifically designed for valuation information should be based at least on the ISO/TC 211 set of standards</b> Efficient and effective land administration system for valuation information compatible with this part of ISO 19152 LADM shall be modelled using or extending the core LADM concepts, namely party, RRR, BAUnit, spatial unit, versioned object, which are all based on source documents. This statement also implicitly implies that it should be modelled in accordance with ISO standards including ISO 19107 — Spatial schema, ISO 4217 — Currency codes and so on.
Requirement 4-2 'Valuation Information Management'	<b>Effective systems are needed to manage valuation information</b> Appropriate valuation information management systems (e.g., a registry or a database) using this part of ISO 19152 LADM should be developed by public authorities for fair and timely valuation of tenure rights in order to promote broader social, economic, environmental, and sustainable development objectives. Input (e.g., legal, locational, physical, environmental characteristics of valuation units, and transaction prices) and output (e.g., value and valuation procedures) data in property valuation processes shall be identified, compiled, recorded, managed and maintained in such systems for effective valuations.
Requirement 4-3 'Linked Public Registries'	<b>Valuation registry should be linked to the distributed registries needed in the valuation processes</b> Uniform and accurate valuation of property units requires correct, complete, and up-to-date property data. The fundamental element underpinning property valuation are public registries, which accommodate regular data maintenance and updating of property



	characteristics, ownership details and transaction information. An efficient land administration infrastructure shall link valuation registries to the other distributed public registries such as cadastre, land registry, property price registry, address, and building and dwelling registries.
Requirement 4-4 'Valuation Unit Registration'	<b>Valuation units should be clearly specified</b> Effective valuation information management shall support the registration of each valuation unit and their required characteristics. The classification of valuation units and the required characteristics of each valuation unit should be explicitly specified for each valuation process. The required characteristics may be obtained through (1) an existing registry or (2) valuation information registry, itself. A valuation information registry may be developed at the local, regional or national level.
Requirement 4-5 'Valuation Procedure'	<b>Valuation procedures should be transparently shared</b> Valuation information management systems compatible with this part of ISO 19152 LADM shall support the determination of value of each valuation unit in accordance with published procedures, where possible based on market values and computer-assisted mass valuation systems.
Requirement 4-6 'Transaction Prices and Statistics'	<b>Efficient information systems for valuation requires to record transaction prices, and to publish indices related to the prices</b> Efficient land administration system for valuation information management compatible with this part of ISO 19152 LADM shall support the registration of transaction prices and the publication of sales statistics regularly
Requirement 4-7 'Valuation Source Document'	<b>Reference to valuation source should be supported</b> All valuation information management systems shall support shall make use of the VM_ValuationSource class to support references to source documents.
Requirement 4-8 'Value Dissemination'	<b>Property values and processes should be transparently shared with public</b> Valuation procedures, processes and results shall be transparently shared with general public. Timely and effective dissemination of property values as well as input information related to valuation processes to general public is an essential part of a transparent and efficient valuation system. For this purpose web-map based dissemination is the preferred, and in case of apartments, the 3D web-maps may be preferred.

Table 4. The proposed requirement for LADM Edition II Part 5

Requirement name / Solution	Requirement Description
Requirement 5-1 'Core LADM Conformant'	<b>A land administration system specifically designed for spatial plan information should be based at least on the ISO/TC 211 set of standards</b> Effective and efficient land administration systems for spatial plan information are compliant with this part of ISO 19152 LADM shall be based on LADM core, namely Party, RRR, BAUnit, SpatialUnit, 2D/3D representations (from 19107), VersionedObject, and all of these are based on source documents.
Requirement 5-2 'Plan Information Dissemination'	<b>Spatial plan information should be visualised and disseminated</b> Spatial plan information systems using this part of LADM shall allow open dissemination and clear visualization (2D/3D) plan information.
Requirement 5-3 'Plan Information Monitoring'	<b>Participatory spatial plan information monitoring should be supported</b> Spatial plan information systems shall support participatory plan monitoring to detect challenges and evaluate alternative scenarios for intervention making as well as achieving SDGs.
Requirement 5-4 'Plan Unit and	<b>Spatial plans can be organised with plan units (homogenous, smallest planning unit) in blocks</b>

Block Relationship'	Spatial plan information compliant with this part of LADM shall organize plan units (plan zones) in plan block, as accepted plans by the relevant authorities for specified time interval.
Requirement 5-5 'Spatial Subfunction'	<b>All functions and subfunctions should be supported</b> Effective land administration systems for spatial plan information compliant with this part of ISO 19152 LADM shall provide extensible code list for the spatial (sub)functions of plan units and plan blocks according to national/local regulations.
Requirement 5-6 'Plan Group Hierarchy'	<b>Spatial planning hierarchy should be supported</b> Spatial plan information shall support the planning hierarchy (from national to local) via hierarchical plan groups.
Requirement 5-7 'Permit Registration'	<b>Permit registration should be supported</b> Efficient and effective spatial plan information management system using this part of ISO 19152 LADM shall support permit registration and relating this to the relevant plan unit.

Figure 1 depicts the package structure of LADM Edition II, designed in a way that meet the requirements. The “Party”, “Administrative” and “Spatial Unit” packages are common packages in Part 1 as well as in Part 2. The newly added packages in Part 3 are “Party Group” and “Source Group”, in Part 4 the “Valuation information” package is introduced, while in Part 5 the “Spatial plan information” package.

For the common packages, in Part 1 the terms defined in these packages are only introduced, while the detailed description (attributes, data type, relationships, multiplicities, constraints, etc.) of these packages is included in Part 2. The “Generic conceptual model” package, which contains the basic requirements on which each part of Edition II is based, is included in Part 1, while the “Survey and representation” subpackage is specified in Part 2. Part 4 and 5 have been designed as a single package, both based on the definitions in Part 1 and 2. Part 1 and Part 2 together form an application schema as well as Parts 1, 2, 3, 4 and 5.

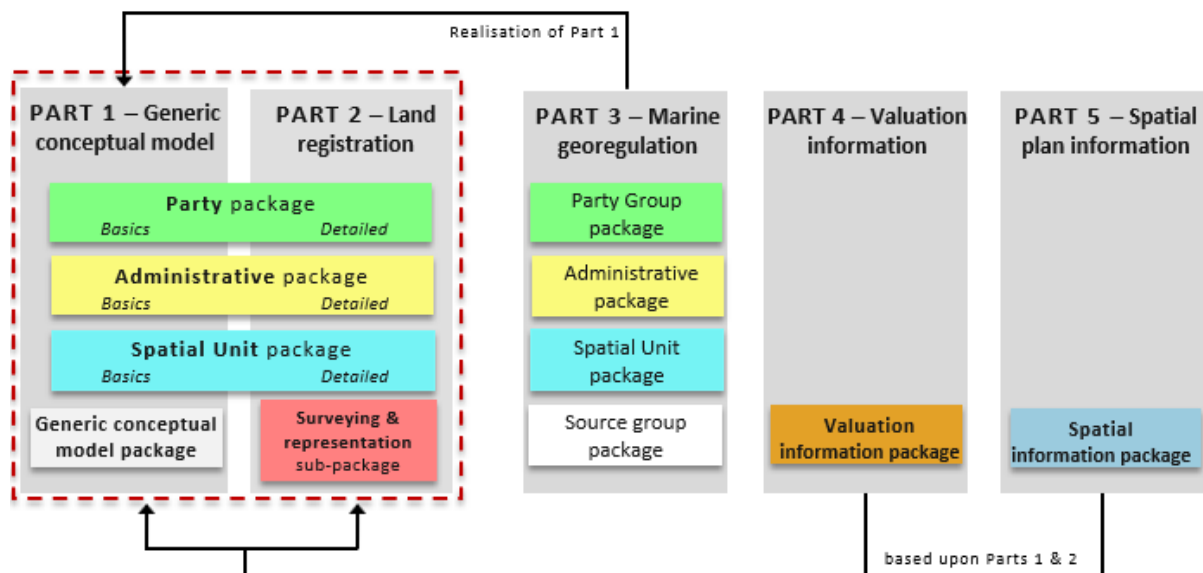


Figure 1. Parts and Packages Design of LADM Edition II

## 4. CONCLUSION

To conclude, the requirements-based approach provides many benefits:

- stakeholder within the domain can express their needs explicitly,
- standards readers can have a very clear and to the point introduction to the domain,
- standards developers have a solid basis to develop and justify their models,
- standards users can use the Abstract Test Suite (ATS), in Annex A of the various parts, to check of their implementation in compliance for that part/package/class of interest.

The operationalization of the LADM Edition I creates opportunities for LA service providers and vendors of Geographic Information Systems (GIS), Document Management Systems (DMS) and Database Management Systems (DBMS) to offer innovative products, services and applications for LA. This in turn enhances the ability of land registry and cadastral organizations to design, develop, implement and maintain their systems with greater efficiency. LADM Edition II extends this capability to marine georegulation, property valuation and spatial planning organizations. In addition, 3D aspects are further supported by new developments (e.g., refined survey model, new types of spatial units, 3D spatial profiles, BIM/IFC as design source). It should be noted that other parts (parts 4 and 5) also support 3D in all aspects.

LADM Edition II adds capabilities to support marine georegulation (not presented in this paper), valuation information, spatial plan information (supporting spatial development) and is closer to implementation (also technical models and processes). This makes LADM Edition II's coverage of land administration/georegulation more complete, which is important if the aim is to harmonize models from these closely related LA sub-domains. The positive votes received on the parts may indicate that the international LA community is satisfied with the proposed refinements and developments.

Part 6 is planned to cover a methodology for developing a LADM country profile, an abstract framework for representing LA workflows (processes), a metamodel for structuring and managing semantically enriched code list values, and support for different encodings (e.g., GML, INTERLIS, RDF, GeoJSON, etc.). In addition, Part 6 is expected to include the OGC API family of standards-compliant recommendations for the development of interoperable LADM schema-based information systems. It will be investigated how well blockchain and ledger technologies can be used to implement the various components of LA systems. Furthermore, the relationships between the LADM and the instruction guidelines for property measurement, such as the International Property Measurement Standards (IPMS) and the International Land Measurement Standard (ILMS), is planned to be included in Part 6.

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