Developing the Refined Survey Model for the LADM Revision Supporting Interoperability with LandInfra

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Published in:
FIG e-Working Week 2021

Publication date:
2021

Document Version
Publisher's PDF, also known as Version of record

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Key words: LADM, LandInfra, Survey Model, Land Administration, Interoperability

SUMMARY

The origin of surveying has a close connection with the designation of land boundaries, while cadastral surveying is a means of defining the limits of properties, thus forming the basis for land administration, serving as an important tool to gather, assess, and update geographical spatial data. Accurate description and record of land are the fundamentals to their rational use and conservation and form the core of well-established Land Administration Systems (LASs). Although surveying models and approaches are important for Cadastres and LASs, they are not always documented in detail, while with the rapid advances in technology and geoinformation they need to be revised quite often.

The ISO 19152:2012 Land Administration Domain Model (LADM), which focuses on standardised modelling of information at the conceptual level, has a dedicated sub package for Spatial and Surveying representation. The first edition of the standard provides multiple spatial representations, and the ongoing LADM revision shall support a broad range in surveying and data acquisition approaches and accuracies, considering the evolution of technology and the encodings used in practice. A conceptual model of the refined survey model is expected to be included in Part 2 of the new edition of the standard, while its technical implementation(s) covering both 2D and 3D boundaries in Part 6.

This paper aims to present the fundamentals of the refined Survey Model of LADM Edition II, considering the need to support the interconnection with the ever-evolving surveying methods and acquisition techniques in a standardised way, including among others the Galileo High Accuracy Services requirements and the alignment with other standards, as well as participatory methods. One of the standards which synergy with LADM is investigated in this paper is the OGC LandInfra, and specifically Part 6 “Survey”, that provides a framework for information about observations, processes and their results collected during survey.

The development of the proposed model was informed by two case studies using survey plans according to Danish practice and cadastral data from the Hellenic Cadastre.

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1. INTRODUCTION

The primary purpose of a Land Administration System (LAS) is to support the processes of recording and disseminating information about the ownership, value and use of land and its associated resources. Today, despite the great diversity of Land Administration Systems that exist worldwide, they do present commonalities. One of them is the surveying process, which leads to the description and delineation of the natural and artificial features of the earth. Although surveying models and relevant approaches are important for Cadastres and LASs, they are not always documented in detail, while with the rapid advances in technology and geoinformation they need to be revised quite often. The number of techniques and data acquisition methods has dramatically increased in the last years and vary a lot, from conventional surveys to image-based approaches, UAVs, mobile mapping techniques, laser scanner sensors, satellite systems, etc.

The origin of surveying is closely related with the designation of property boundaries, while surveying for cadastral applications is the basis for Land Administration Systems (LASs), serving as an important tool to gather, assess, and update geographical spatial data (Schofield and Breach 2007). Accurate knowledge of land and an accurate description and record of such knowledge are the fundamentals to their rational use and conservation and form the core of well-established LASs.

The first edition of ISO 19152:2012 LADM has a dedicated sub package for Spatial and Surveying representation, as presented in Section 2, providing multiple spatial representation possibilities from text to volumetric parcels. To date, LADM has been implemented at the country level via the development of local profiles and from those developments the need to further support the spatial representation part of LADM is highlighted. What is more, the evolution of technology and surveying equipment and the encodings used in practice force the enhancement of LADM interoperability.

As an ISO standard, the LADM is subject to periodic revision, typically in a 6 to 10-year cycle aiming to extend the current scope of the standard, as well as to refine some of the existing parts of the current version (Lemmen et al., 2019). Currently, LADM revision is ongoing, and among others, the valuation, spatial planning, and marine extensions will be included in the revised version of the standard, together with the enhanced support of surveying model, to support a broad range in surveying and data acquisition approaches and accuracies. The development of a refined survey model aims to address improvements in workflows of land management organisations, extend the functionality of cadastral surveying techniques and facilitate interoperability with technical standards used to describe surveying approaches and results. A conceptual model of the refined survey model is expected to be included in Part 2 of the new edition of the standard, while its technical implementation(s) via GML/ JSON formats/ RDF/ INTERLIS, covering both 2D and 3D boundaries in Part 6.

The paper is structured as follows: Section 2 presents the surveying functionality of LADM edition I, while Section 3 lists the features and structures to represent the surveying process that LandInfra offers. Therefore, based on that, Section 4 introduces the LADM Refined Survey Model in line with LandInfra's directions, aiming to support a wide range of surveying methods, accuracies and processes. To verify it, two use cases, in Denmark and Greece are presented, while the last section is devoted to conclusions and future work.

2. LADM surveying functionality

The need for functionality to represent a broad range of spatial units, with a clear quality indication was recognised and supported by Edition I of LADM. 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, see Lemmen (2012), Lemmen et al. (2015), van Oosterom and Lemmen (2015).

The LADM is based on accepted and available spatial schemata, such as that published in ISO 19107:2003. In LADM a survey is documented via spatial sources. A set of measurements with observations (distances, bearings, etc.) of points, is an attribute of LA_SpatialSource. The individual points are instances of class LA_Point, which is associated with LA_SpatialSource. 2D and 3D representations of spatial units use boundaryFaceString (2D boundaries implying vertical faces forming a part of the outside of a spatial unit) and boundaryFaces (faces used in 3D representation of a boundary of a spatial unit). Coordinates themselves either obtained from points or are captured as a linear geometry.

The Surveying and Representation sub package in LADM includes basic concepts for modelling the bounding elements for spatial units. These include points (LA_Point), 2D boundary face strings (LA_BoundaryFaceString) and 3D boundary faces (LA_BoundaryFace) (Figure 1).

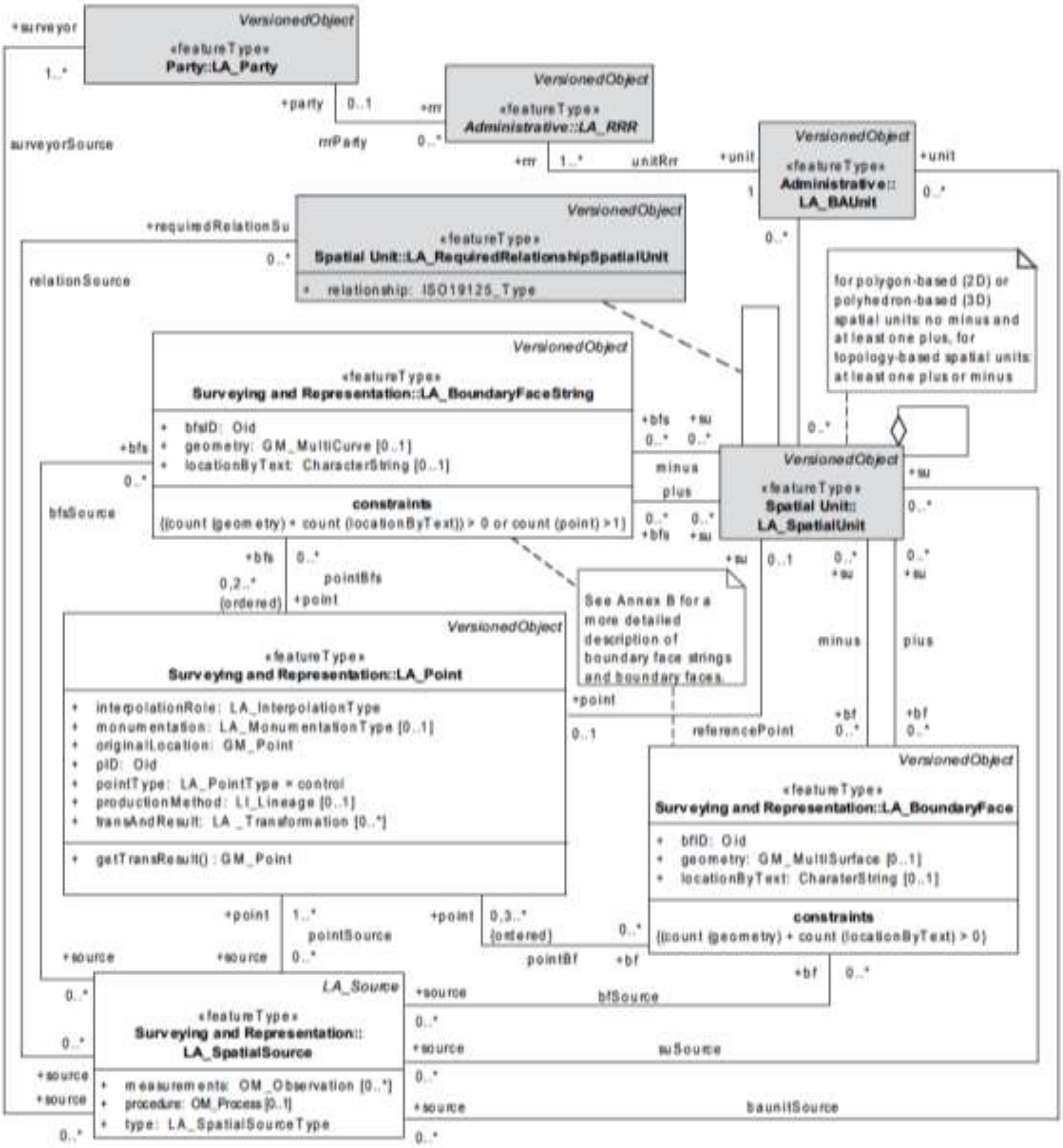

Figure 1. Content of Surveying and Representation Subpackage with associations to other (basic) classes (ISO19152, 2012)

3. LandInfra surveying functionality

The scope of the Land and Infrastructure Conceptual Model is land and civil engineering infrastructure facilities. Subject areas include facilities, projects, alignment, road, railway, survey, land features, and land division. The standard regards the surveying needed to locate infrastructure facilities on the terrain in compliance with interests in land. Infrastructure facilities are improvements constructed and operating on land. Though often not considered to be infrastructure, buildings are included to a limited extent. The target audience of LandInfra spans civil engineering (e.g., road and rail), surveying, land parcel, facility and asset management, and government information communities. It is applicable throughout the entire facility life cycle, including planning, design, construction, operations, maintenance, and removal. LandInfra represents a seminal venture into GIS-CAD-BIM integration.

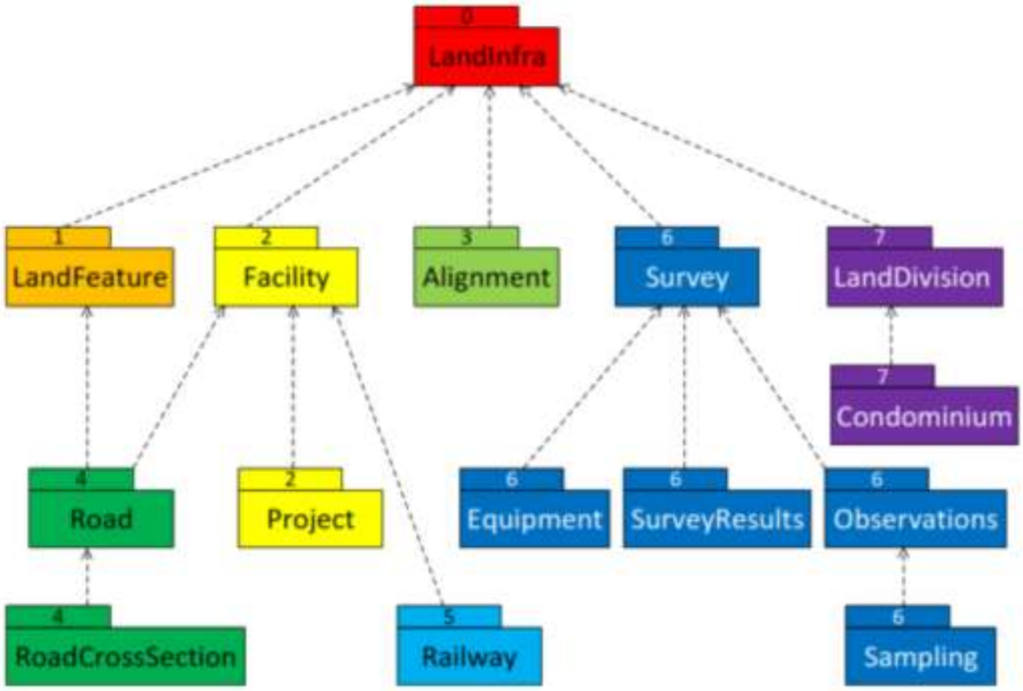

Figure 2. LandInfra Requirements Classes grouped into InfraGML Parts (OGC, 2017)

This paper focuses on the survey and land division subject areas of the standard. The LandDivision part of LandInfra regards information about parts of the land surface separated by existing and new boundaries and delimiting ownership and other rights in land. This part of LandInfra provides the context for fieldwork, including measurements and marking of boundaries.

A LandInfra dataset may contain any number of Surveys to cover the acquisition of points, lines, surfaces and properties of features of interest. The primary focus of the Survey package is to have the possibility of recording and reprocessing the observations of the acquired objects. The Survey package is divided into sub-packages because of the number of classes into the Observations, SurveyResults and Equipment packages. The survey package is the umbrella for all survey information and specifies the "header" information about a survey, such as the purpose, type, and surveyor. The survey may include additional information about its observations, equipment, and results.

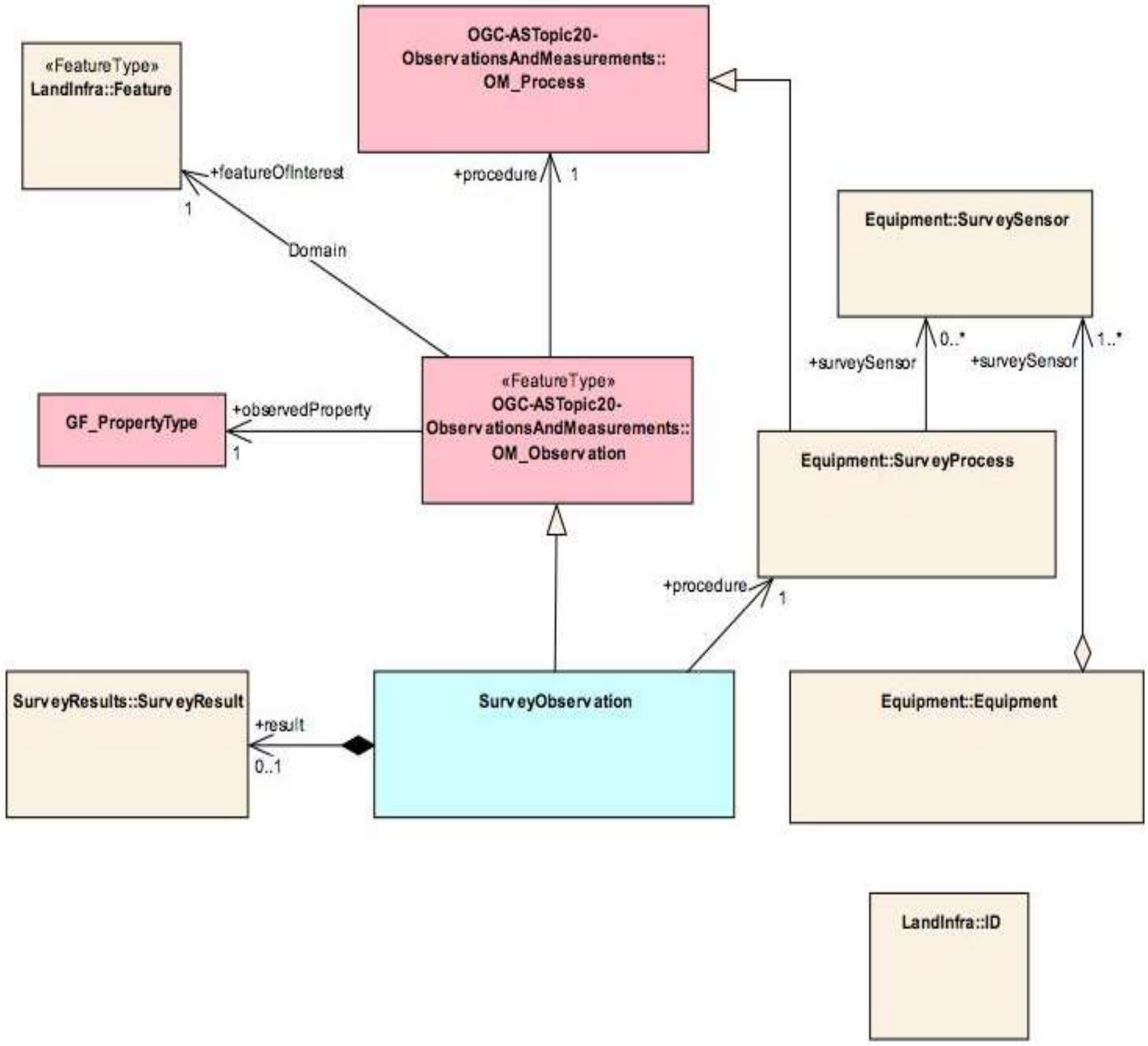

Figure 3. SurveyObservation and OGC Abstract Specification Topic (OGC, 2016)

A LandInfra SurveyObservation is a specialization of OM_Observation defined in ISO 19156 (ISO, 2011) and a LandInfra dataset may contain any number of Observations to organize all kinds of observations based on the location where the measurement has been taken. Observations are organized in different Setups to have the possibility to reprocess the Observations. A featureOfInterest is the real-world object whose properties are under observation, or is a feature intended to sample the real-world object, as described in Clause 9 of ISO 19156. For SurveyObservations holding a SurveyResult with a Targetpoint, the feature would most likely be a LandInfra SurveyMark.

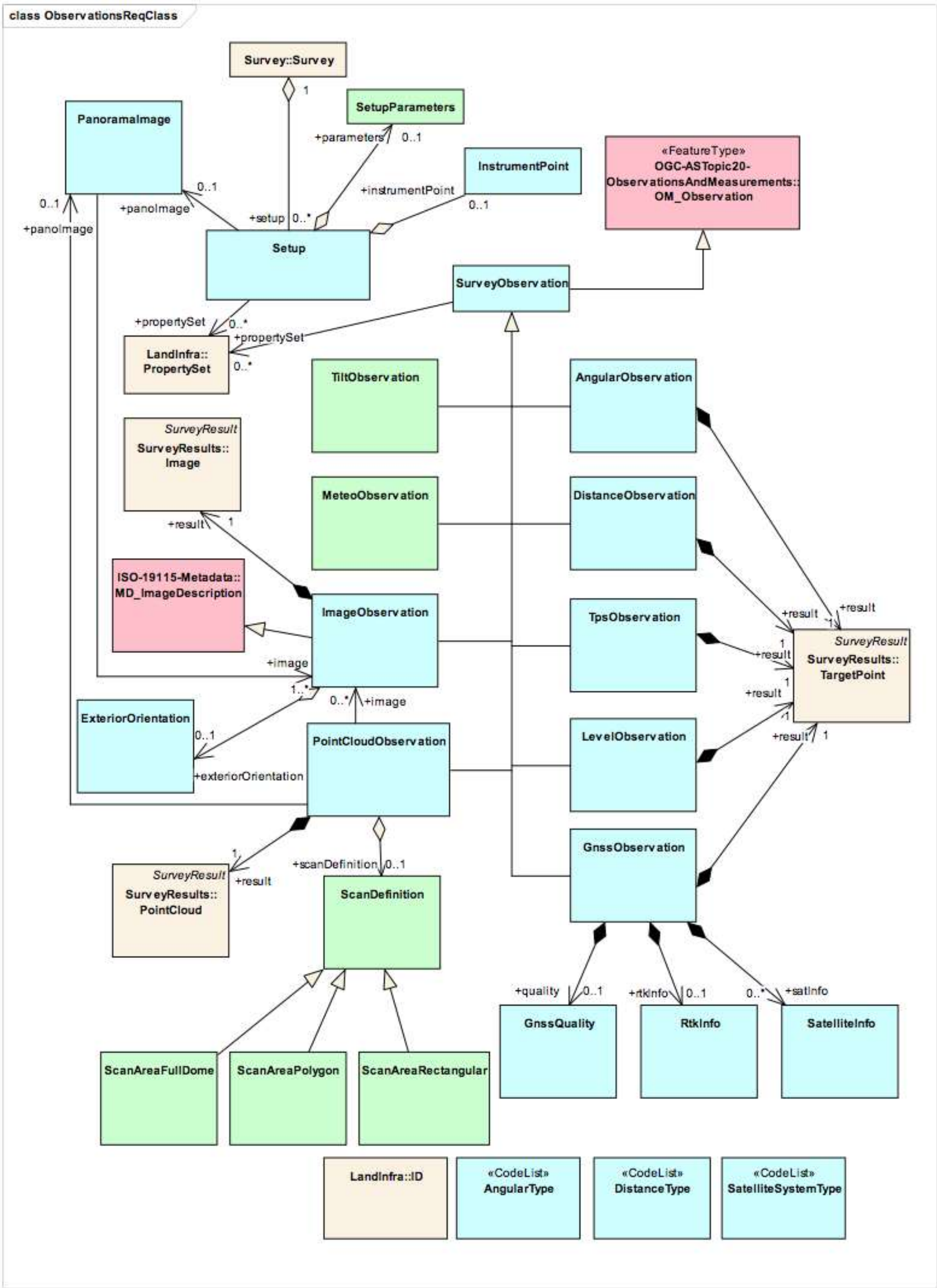

Figure 4. LandInfra SurveyObservation class (OGC, 2016)

Depending on national regulations and survey purposes, different sensors and processes have to be used for capturing the existing and marking the new points in the reality during the fieldwork. This includes observation corrections, optional sensor calibration and also adjustment routines applied over all raw observations. The LandInfra Survey package holds information about the field book for controlling, correcting, reprocessing, documenting and finally archiving this work including all details about the process and how the results have been accomplished.

4. LADM Edition II refined according to LandInfra's surveying part

To initiate the discussion on the revision of the LADM Survey Model, Shnaidman et al. (2019) have proposed improvements in workflows of land management organisations and extended functionality of cadastral surveying techniques. To enhance interoperability with other standards, mature approaches on surveying models are now examined to be included at the second edition of LADM. Among them is the OGC 15–111r1 Land and Infrastructure Conceptual Model Standard, and specifically Part 6 Survey, which provides a framework for information about observations, processes and their results collected during survey work (OGC, 2016). The ISO 19152:2012 Land Administration Domain Model (LADM) and the LandInfra exist within the domain of Land Administration, having both similarities and discrepancies, calls for the alignment of the standards.

There are many papers discussing the synergy and the relationship between LandInfra and the LADM, see for instance Cagdas et al. (2016), Kalogianni et al. (2017), Kara et al. (2018), Lemmen et al. (2017), OGC (2019), Stubkjær et al. (2018), van Oosterom et al. (2018). From the research carried out and the expertise of the authors at the two standards it is concluded that the conceptual scope of LADM and LandInfra is partly overlapping (survey, land parcels, apartments) and partly complementary.

Though there is conceptual overlap, the two standards have different perspectives on the world: national registrations and databases (state-based LADM) vs. projects and files (event-based LandInfra) views. LandInfra aims to model project datasets and the core/root of the model is the class LandInfraDataset, which is an aggregation class containing all the project information. In the spatial development lifecycle, a project causes a change or event. LADM aims to model (national) registrations and the core/root of the model is VersionedObject from which all other classes inherit. This results in a state-based representation in a land administration database, where all object instances have a beginLifespanVersion and possibly endLifespanVersion attribute. The actual harmonization of these different views on modelling can be found by realizing that a project document is an event, which is causing a change in the state. So, we propose to make an association between the VersionedObject (root of all classes in LADM) and the project document causing the change (LandInfra project document stored in LA_Source); see Figure 6. For example: in a survey a new parcel boundary is defined and used to split an existing parcel. This information is included in the LandInfra document. Then this document is submitted for registration (at the lifeSpanStamp system time) and accepted at a certain moment in time by the land administration authority (at the acceptance user time), resulting in a temporal model. Note that the user times are optional. The registration (and acceptance) time of the source document should be equal to the beginLifespanVersion or endLifespanVersion attribute (and beginValidLifespanVersion or endValidLifespanVersion) of the object instances created, changed, or deleted in the registration. This is indicated by the constraints attached to the associations between the two core classes.

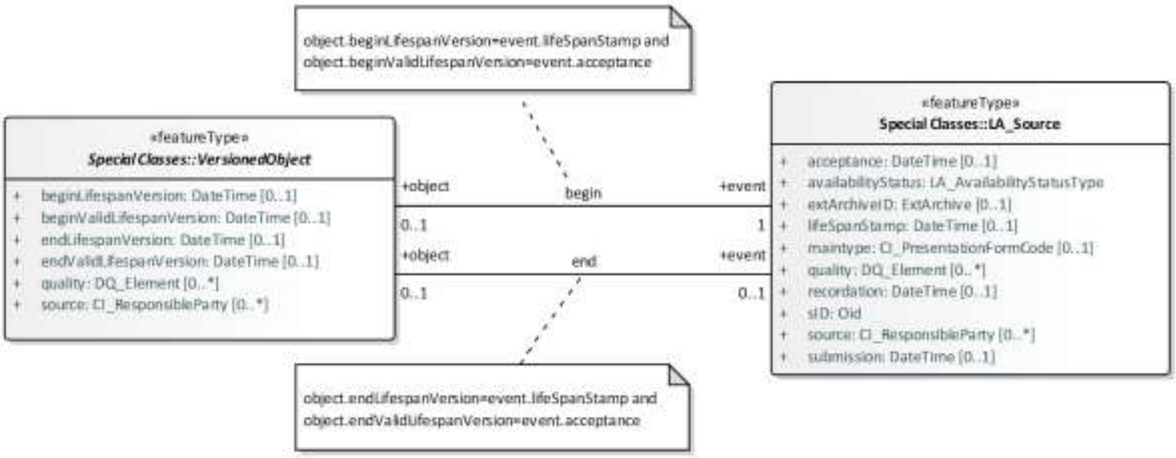

Figure 5. The harmonization of the different modeling views: state and event based

Given this background, the proposed conceptual model of the LADM Refined Survey Model has been modelled and it is presented in Figures 6, 7, 8 and 9, while Figures 10 and 11 depict the proposed code lists values for the new attributes and classes. The LADM supports the increasing use of 3D representations of spatial units, without putting an additional burden on the existing 2D representations. Another feature of the spatial representation within the LADM is that there is no mismatch between spatial units that are represented in 2D and spatial units that are represented in 3D. What is more, the LADM refers to the ISO 19156:2011 Observations and Measurement Standard (ISO, 2011) which is essentially a survey model, though a very generic one. To facilitate a comprehensive spatial description of the survey components, the LADM Refined Survey Model includes an improved link to ISO 19156:2011.

To start with, the need to store the geometry of a spatial unit and not the topological relationship is addressed by the new attribute *geometry: GM_Object* at the LA_SpatialUnit class. What is more, taking into account the broader scope of the revised version of the model and the need to support the description of a wide range of spatial unit types, the categories of the legal spaces of cadastral objects (currently: LA_LegalSpaceBuildingUnit and LA_LegalSpaceUtilityNetwork, cf. Figure 1) are enriched, with the newly added subclass at the LA_SpatialUnit, the LA_LegalSpaceInfrastructure. This class serves a reference to the physical (technical) description of the different types of infrastructure objects (i.e. tunnels, bridges,etc.).

Furthermore, the concept of "Integrated Source" is suggested, modelled as an association between LA_AdministrativeSource and the LA_SpatialSource classes (Figure 7). Different source types are represented via assignment of multiplicity, where "0" represents a case of a pure Administrative or Spatial source, whereas "1" illustrates a situation where a document contains both attributes from LA_AdministrativeSource as well as from the LA_SpatialSource. Additionally, in order to explicitly express the purpose of the survey, an association class LA_SurveyRelation is proposed between the LA_SpatialSource and LA_SpatialUnit.

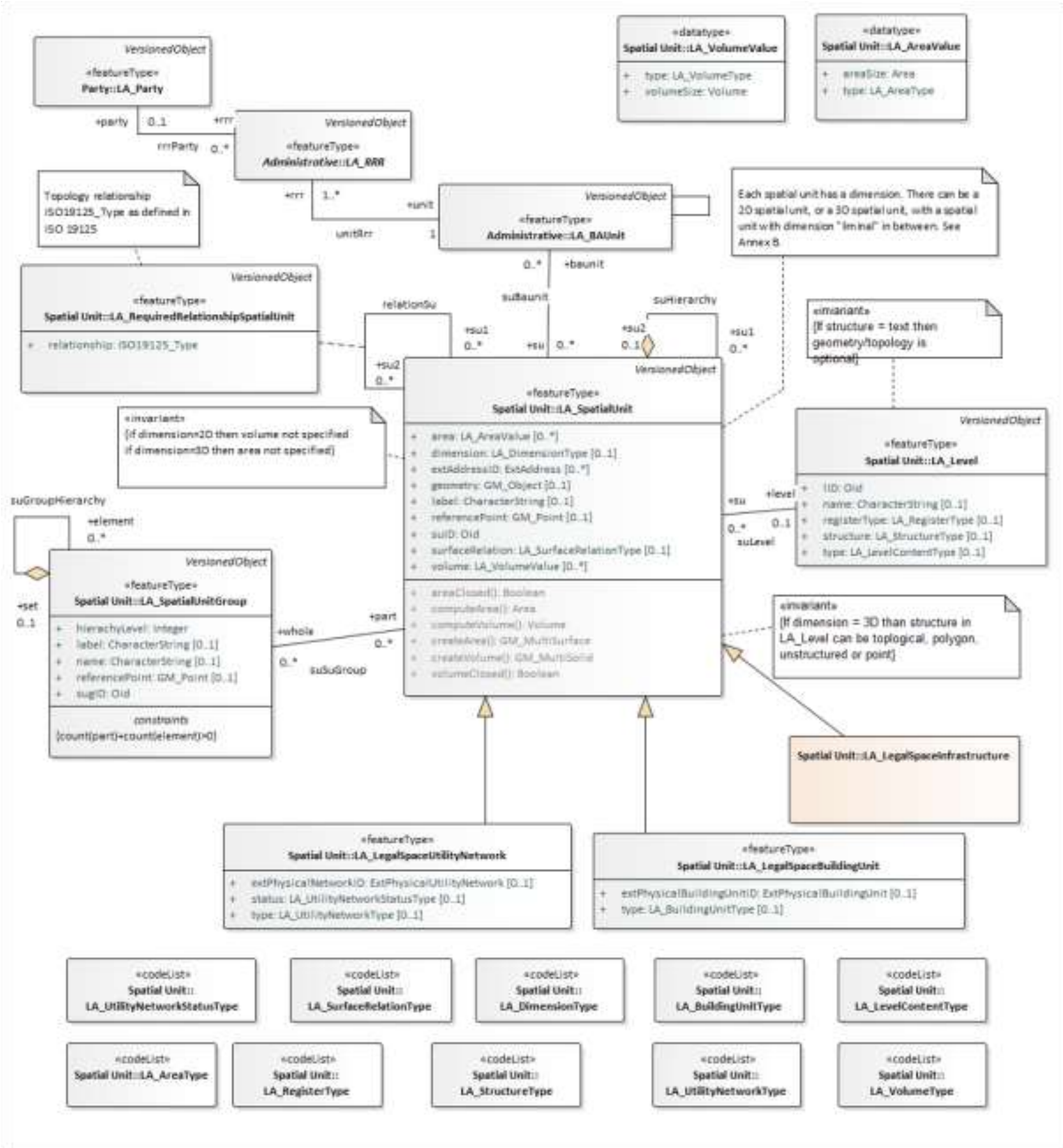

Figure 6. Updated LA_SpatialUnit class and subclasses

The LA_SpatialSource class as defined in LADM Edition I, is being updated and extended. Specifically, the attributes of the class are now the following: *type* (defining the type of the source, was already an existing attribute in Edition I), *media* (portraying the source document media type), *automationLevel* (illustrating the assorted process automation level types) and *surveyPurpose* (including all the individual survey purpose types).

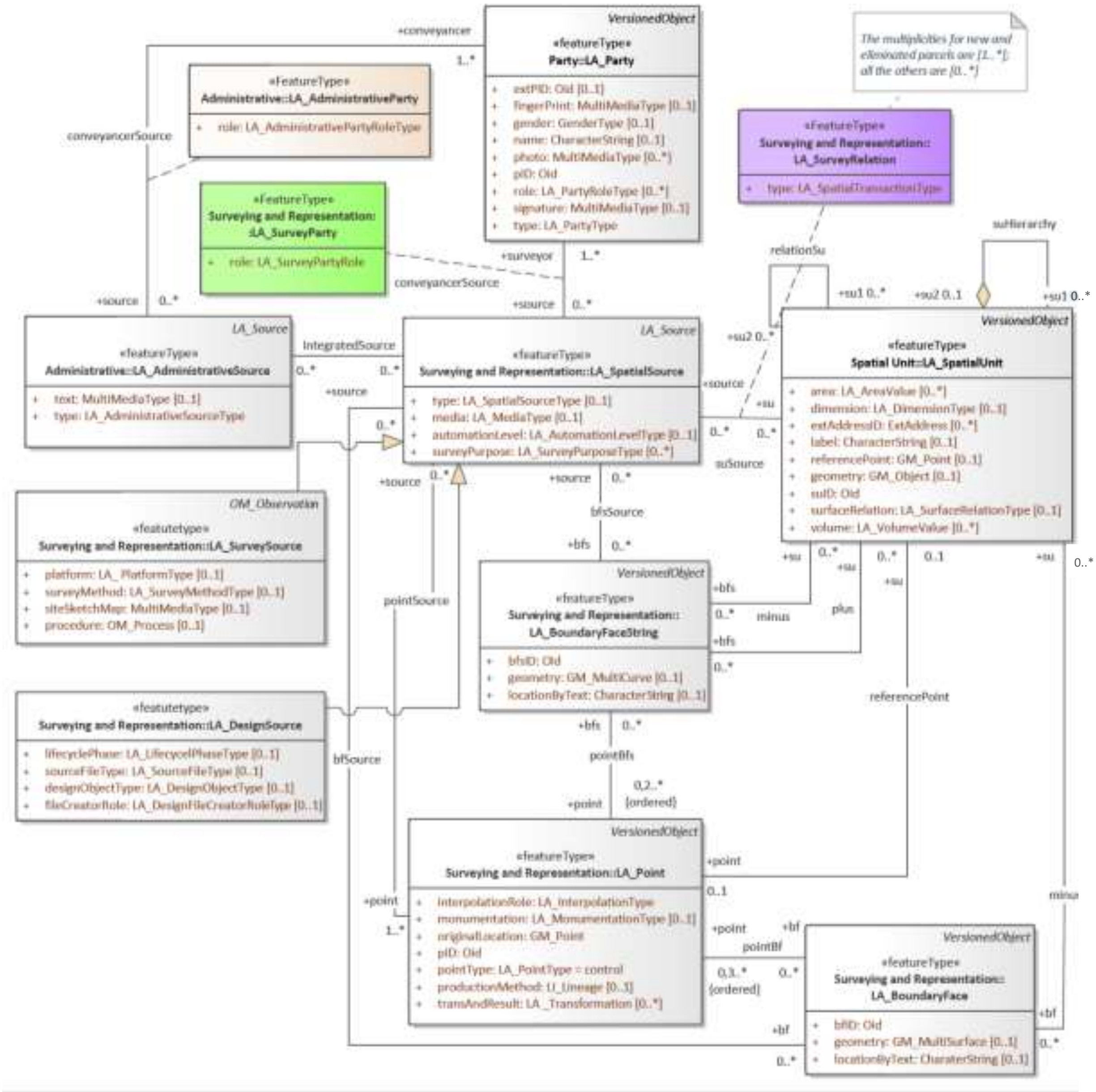

Figure 7. Overview of the proposed Refined Survey Model

It is noted that the attribute *measurements: OM_Observation* that was included in LADM Edition I, describing the set of measurements with observations of points, has been removed, as the link with ISO19156 is being refined and updated more detailed. With this structure, an LADM operationalisation may contain any number of Observations to organize all kinds of observations based on the location where the measurement has been taken, similar to the observations' organisation of OGC LandInfra. Therefore, the LA_SurveySource class becomes a subclass/ specialisation of the OM_Observation defined in ISO 19156. It is noted that the individual points are instances of class LA_Point, which is associated with LA_SpatialSource. While it is not required that the complete spatial unit is represented, a spatial source may be associated with several points. Geodetic control points, including multiple sets of coordinates for points, and with multiple reference systems, are all supported in the LADM.

What is more, there are two subclasses of LA_SpatialSource being proposed; LA_SurveySource and LA_DesignSource, to provide more insights at the spatial source registered at the system. A survey is documented with survey sources, instances from class LA_SurveySource. This may be the final (sometimes formal) documents, or all documents related to a survey. Sometimes, several documents are the result of a single survey. LA_SurveySource class consists of the following attributes: *procedure* (which was included as attribute in LA_SpatialSource in Edition I), *platform* (depicting possible platform types used for the survey), *surveyMethod* (presenting whether the survey is formal or participatory) and *siteSketchMap* (which is the draft hand sketch map designed by the surveyor on the field to support the surveying process and the office works that follows).

The subclasses of the LA_SurveySource relates to the various survey acquisition methods that could be used during a survey, specifically: distance observations, angular observations, level observations, image-based, GPS GNSS and/or using Galileo High Accuracy Services, classic total station and point-clouds observations.

For each one of the subclasses proposed to describe the survey acquisition methods that LADM Edition II will support, relevant attributes and code lists have been designed to address the most common observation characteristics for each one of the methods. The proposed model is flexible and supports both formal and participatory surveying acquisition methods.

A design document (e.g. BIM/IFC) is documented with design sources, instances from class LA_DesignSource. A spatial source may be official, or not (i.e. a registered survey plan, or an aerial photograph). Paper based documents (which may be scanned) can be considered as an integral part of the land administration system.

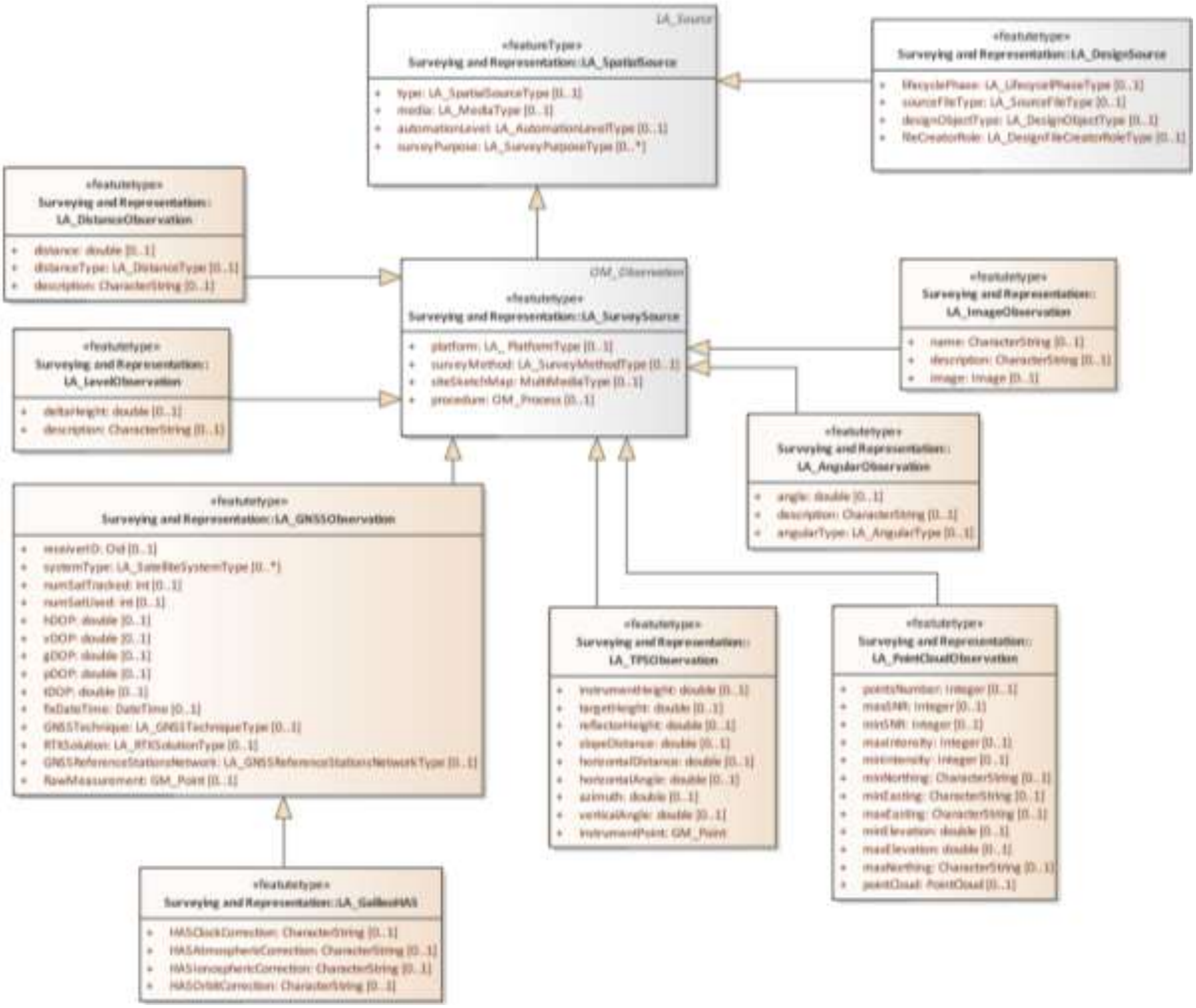

Figure 8. Proposed refinement of LA_SpatialSource

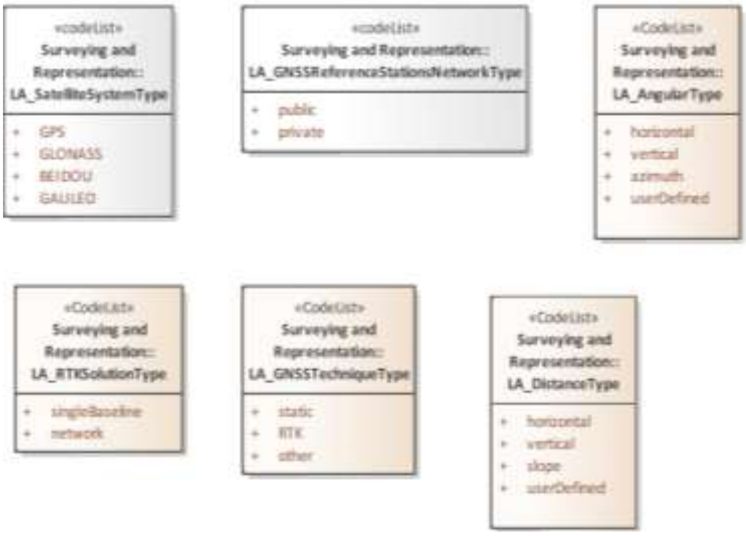

Figure 9. Proposed code lists for the subclasses of the refined LA_SpatialSource

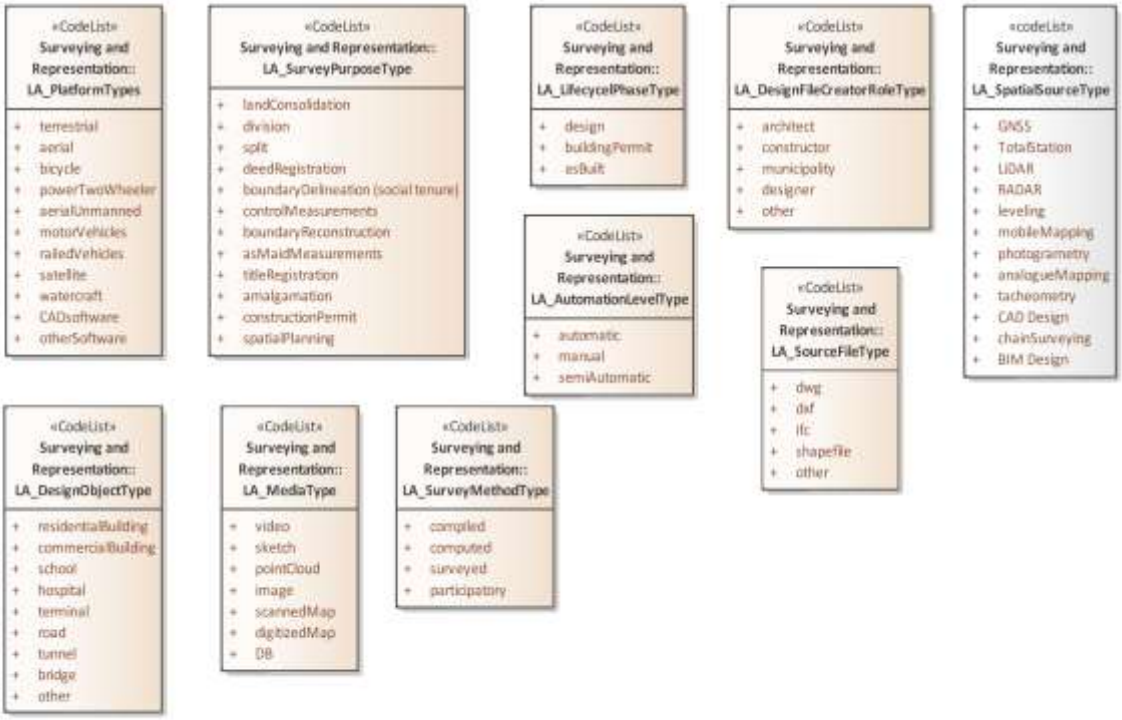

Figure 10. Proposed code lists for LA_SpatialSource, LA_SurveySource and LA_DesignSource classes

5. USE CASES

5.1. Denmark

The potential application in Denmark of the OGC LandInfra/InfraGML standard is illustrated with reference to the survey part of a subdivision process. The organization of cadastre in Denmark and the general outline of a subdivision process is rendered in the report Property formation in the Nordic countries (Kort og Matrikelstyrelsen, 2006), specifically Figure DK-14 and related text. Since 2005, the process is digital, and in their offices, the land surveyors have installed MIA, a digital cadastral and information update system developed by the then National Survey and Cadastre in collaboration with the Danish Association of Chartered Surveyors, and municipal representatives. The MIA system is focused on the exchange with the Cadastre, while preparation of data for set-out is handled by available GIS software. The survey part of the subdivision process is illustrated by Figure 11.

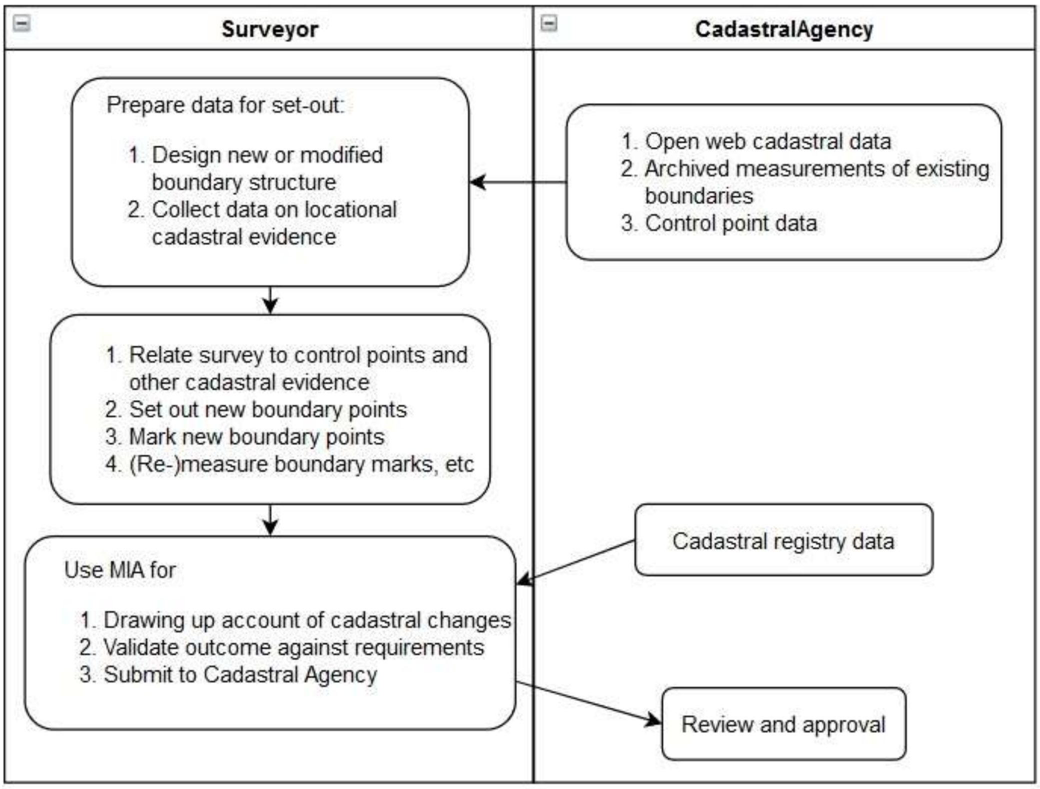

Figure 11. Survey part of subdivision process in Denmark

The preparation of data for set-out addresses two domains: The design of new or modified parcel boundaries, and the need of relating the new cadastral survey to locational cadastral evidence. Clients and society are mostly interested in the former part. In Denmark, the surveyor specifies the layout of new parcels and private roads according to the wishes of the owner and the requirements of spatial planning and easements recorded at the Land Registry. The latter part addresses the important goal of achieving reasonable consistency between cadastral surveys made on the same location, but at different times. Archived measurements of existing boundaries are taken into account, as they often specify the location of existing boundaries, and when best also provides measures to boundary marks, which appear undisturbed since their establishment, and house corners, etc. Together with data on current cadastral map boundaries and monumented control points, they constitute the data set for set-out.

Figure 12a renders existing cadastral boundaries and control points; Figure 12b renders the intended new boundaries (here already on location).

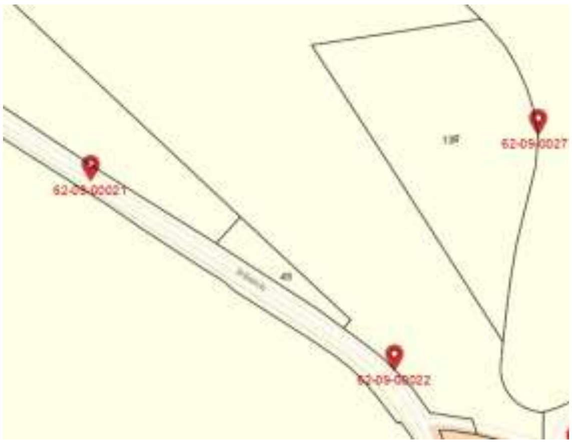

Figure 12a. Cadastral boundaries and control points

Figure 12b. The new boundary points to set out relative to the control points -021, -022, and -277

The OGC LandInfra/InfraGML standard specifies several SurveySensors (7.8.5.3) which could be used for set-out, including total station theodolite (tps) and GNSS. Here, the application of a total station is stipulated. The total station is assumed to have access to a web-based project database, cf. Figure 13.

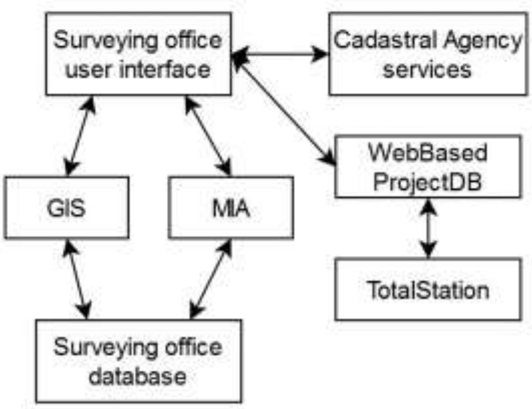

Figure 13. Software components of a survey process in Denmark. The component MIA is described in section introduction

A total station Setup (LandInfra, 7.8.3.1) is performed at control point 62-09-022. Two neighboring control points, -021 and -277, provide further georeferencing, and the new boundary points are staked out. The new boundary points are marked, and another setup is performed at control point -277 to measure the location of boundary markers and current boundary points as control.

The InfraGML rendering of the set-out and the subsequent measurement is verbose, to allow for machine reading of the content.

Figure 14a. Set-out of new boundary points from control point -022

Figure 14b. Measurement of boundary markers, etc. from control point -27

Below, two snippets illustrate a part of the content. The essential fact that the file refers to a set of about 10 XML Schema Definition files, which test for compliance with the InfraGML standard, is not covered. The issues of Average and PointQuality (LandInfra, 7.8.7.6 and .11) are not covered by the snippets. The following snippet renders purpose, time, and details of Setup of InstrumentPoint, here regarding the first setup in -022, cf "Set1p22".

```
<lis:purposeOfSurvey>Determination of new Parcel Boundary</lis:purposeOfSurvey>
  <lis:type xlink:href="http://example.com/surveyType#surveyed" xlink:title="Surveyed"/>
  <lis:setup>
    <liso:Setup gml:id="Set1p22">
        <gml:metaDataProperty><gml:GenericMetaData><gml:TimePeriod>
            <gml:beginPosition>2021-02-24T15:45:29.74</gml:beginPosition>
            <gml:endPosition>2021-02-24T16:40:10.46</gml:endPosition>
          </gml:TimePeriod></gml:GenericMetaData></gml:metaDataProperty>
   <liso:instrumentHeight uom="m">1.5</liso:instrumentHeight>
   <liso:instrumentPoint><liso:InstrumentPoint>
        <gml:name>62-09-00022</gml:name>
        <spatialRepresentation><SpatialRepresentation><geometry>
            <gml:Point gml:id="p22">
            <gml:pos>397266.739 1317052.674</gml:pos>
            </gml:Point>
          </geometry></SpatialRepresentation></spatialRepresentation>
    </liso:InstrumentPoint></liso:instrumentPoint>
```

The set-out of a single point, p55, identified by <gml:resultOf xlink:href="Stake1p55"/>, is specified as follows. The measurement of a boundary mark is recorded in the same structure, only the identification is changed to e.g. "Surv1p55":

```
<liso:observations><liso:Observations>
 <liso:surveyObservation>
  <liso:TpsObservation>
        <gml:validTime/>
        <gml:using xlink:href="DistCorr360Prism"/>
```

```
        <gml:resultOf xlink:href="Stake1p55"/>
        <liso:resultTime><gml:TimeInstant>
        <gml:timePosition>2021-02-24T15:57:56.04</gml:timePosition>
          </gml:TimeInstant></liso:resultTime>
        <liso:bInstrumentPoint>true</liso:bInstrumentPoint>
        <liso:reflectorHeight uom="m">1.5</liso:reflectorHeight>
        <liso:directFace>true</liso:directFace>
        <liso:meanFace>false</liso:meanFace>
        <liso:horizontalAngle uom="gon">5.159058</liso:horizontalAngle>
        <liso:verticalAngle uom="gon">100.000350</liso:verticalAngle>
        <liso:slopeDistance uom="m">126.7648</liso:slopeDistance>
        <liso:horizontalDistance uom="m">126.7648</liso:horizontalDistance>
        <liso:inclinationLength uom="gon">0.000064</liso:inclinationLength>
        <liso:inclinationCross uom="gon">0.000255</liso:inclinationCross>
  </liso:TpsObservation>
</liso:surveyObservation>
```


The snippets illustrate a few, essential elements of the surveying part of InfraGML. In Danish praxis, these surveying data remain within the surveying company. Only point coordinates are to be submitted to the Danish Geodata Agency.

InfraGML covers also the account of cadastral changes regarding ownership, parcel identification and area, etc, to be submitted to the Agency, cf. Figure 11. Relations between the measured Points and further LandInfra classes are illustrated by Figure 15, which renders the classes, which relate Point or LineString with LandParcel. These classes are specified in the LandDivision part of LandInfra, cf. also LandInfra figures 66 and 67.

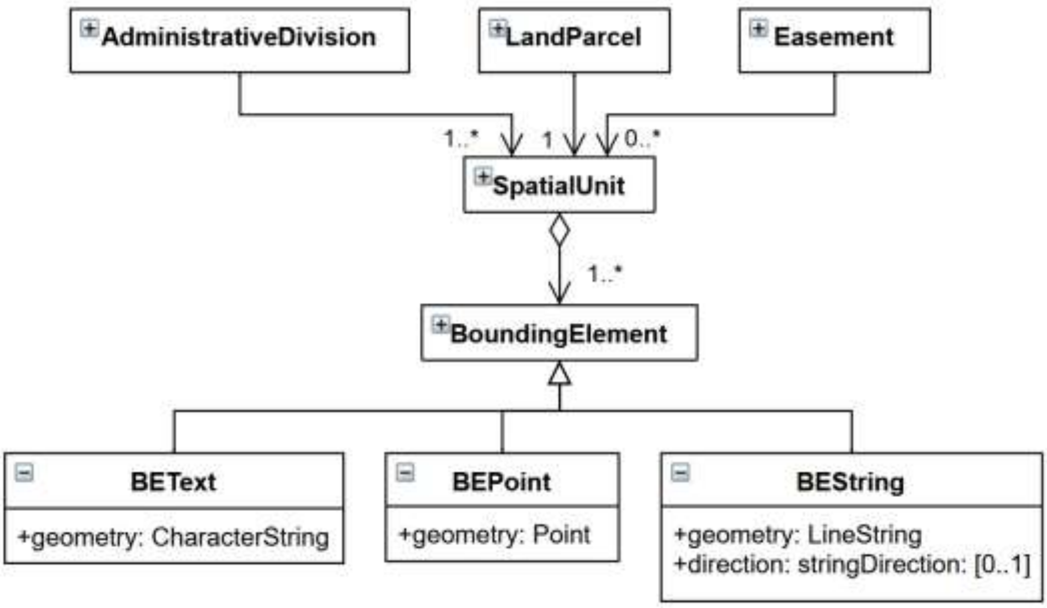

Figure 15: Classes of the LandDivision part of LandInfra, which relate Point measurements to LandParcel, etc. Information extracted from LandInfra figures 66 and 67 (OGC, 2016).

5.2. Greece

The Hellenic Cadastre (HC) is a property-based system that registers and maintains the technical (location and boundaries) and legal information of real properties, linked via a unique National Cadastre Code Number (KAEK). The HC system is electronically accessed by the KAEK, the property address or the personal data. For the geometrical representation of spatial units/ parcels, plans of survey guarantee x/y coordinates in relation to the Greek national reference system (GGRS'87), while older plans in older or arbitrary systems may also exist. Height representation is referenced to the Greek national system, although z coordinates are not stored in the DCDB (van Oosterom, 2018).

The Cadastral Database includes all information (descriptive and spatial) collected during the cadastral survey process. The objects of the cadastral database are organised into logical entities, depending on their feature type. In case a registrable deed affects a spatial change, the applicant needs to have previously filed an application to the competent Cadastral Office and obtain a cadastral survey diagram extract of the properties which will be altered. Assisted by a surveyor/engineer, the applicant can depict these changes in accordance with the provisions of the law and the instructions of the HC. A special procedure is also prescribed in the law in cases of acts effecting spatial changes of a larger scale. The cases that require an update of the existing cadastral database are: subdivision, consolidation of parcels, establishment or abolishment of exclusive use areas (vertical partitions/ easements) and corrections of errors that involve geometric data.

At the following figure, the procedure followed for spatial/ geometric changes at the HC for the case of a parcel subdivision is presented. The process followed for changes of a large scale (urban renewals, land redistributions, etc), is quite different and not presented in this manuscript. It is noted that in respect to the GDPR Regulation about data privacy, all the personal data has been encoded.

The use case refers to a parcel subdivision with KAEK XXXXXXX70001, with initial vertices 2-10-5-6-11-3-2. The new space created is subject to concession to public/common use, in order to grant a special raise of the existing building coefficient by 10% (the initial situation is presented in Fig. 18a). The surveyor measures the vertices of the parcel on the ground, following the surveying guidelines and the new vertices of the modified parcel are determined. Then, the new boundaries are measured and the survey document for the spatial/ geometric changes is being prepared. In this document, metadata regarding the equipment and methodology used to calculate the coordinates, as well as other survey-related information are presented as textual information.

The surveyor compares the information of the new surveying diagram with the corresponding data included in the cadastral diagram provided by the Cadastral Office. If the differences lie within the accepted deviations that the HC regulations have set, then the Geometric Data Correction Diagram is prepared and submitted to the competent Cadastral office, together with all the relevant documents and the notarial deed describing the new situation.

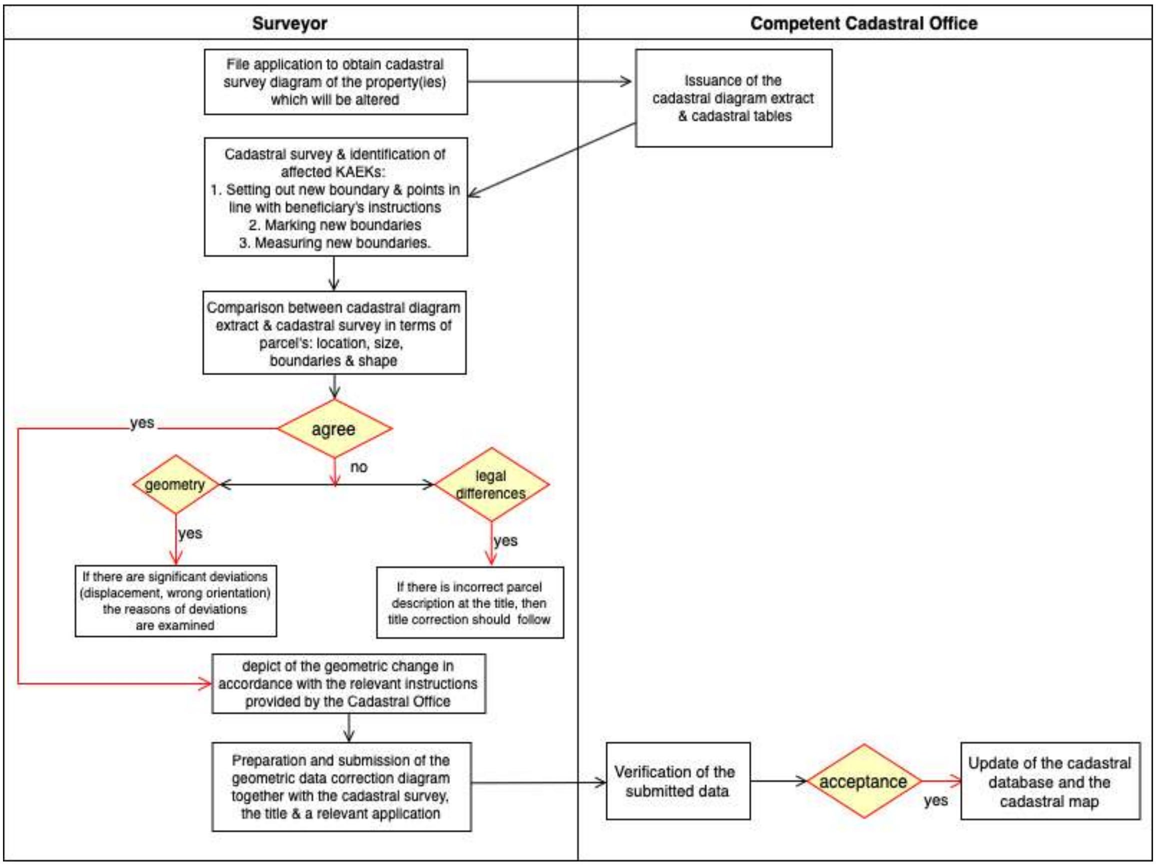

Figure 17. Spatial aspect of the survey process for a parcel subdivision in Greece

Figure 18a. Part of survey diagram depicting the parcel to be subdivided

Figure 18b. Part of the Geometric Data Correction Diagram depicting the new situation

The Geometric Data Correction Diagram (Fig. 18b) depicts the new boundaries of the initial parcel with KAEK XXXXXXX70001, with the updated vertices 10-5-6-11-10 and the new parcel part A1 with vertices 2-10-11-3-2 that is subject to concession to be used as public space / unit with new road's KAEK XXXX2EK001, since every piece of land is considered as cadastral parcel and gets its own unique ID.

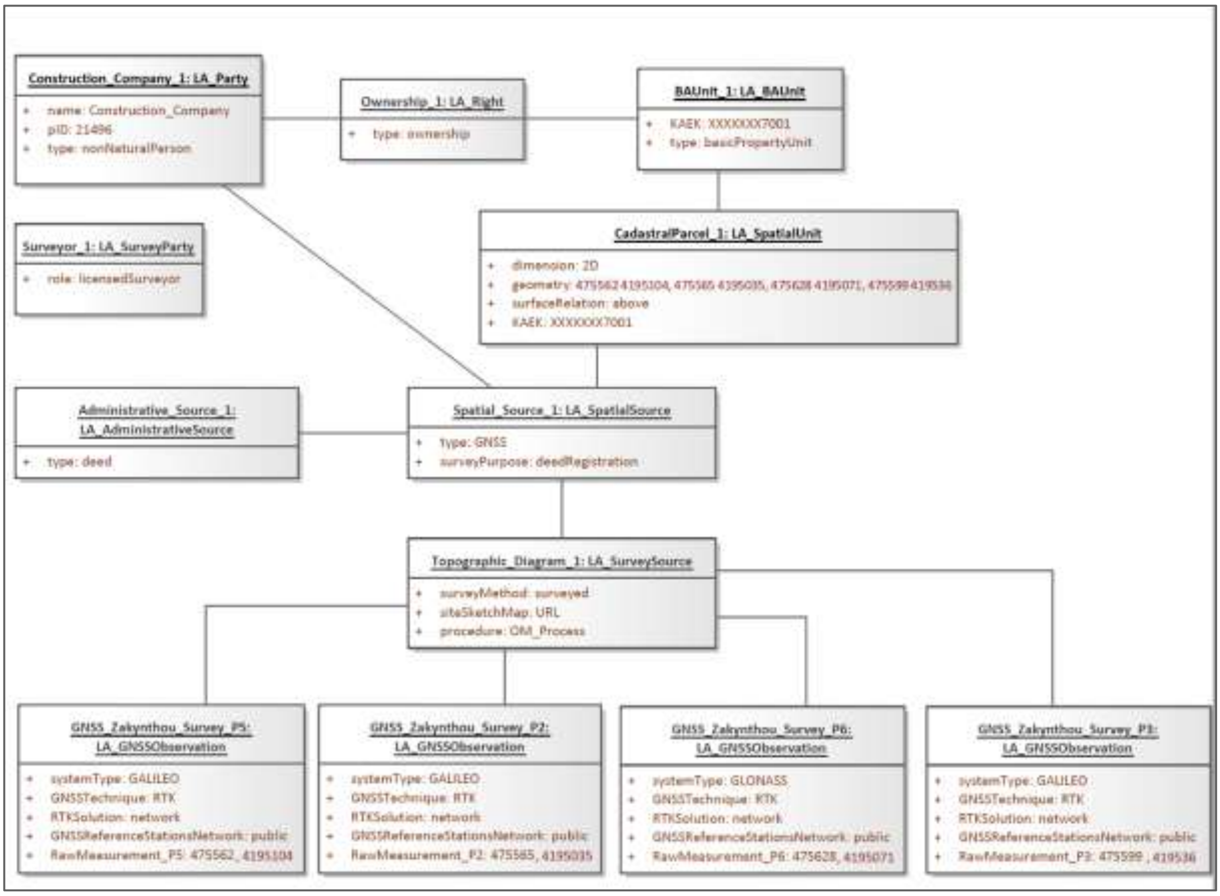

Figure 19. Instance level diagram of the Greek use case at the initial stage (before split)

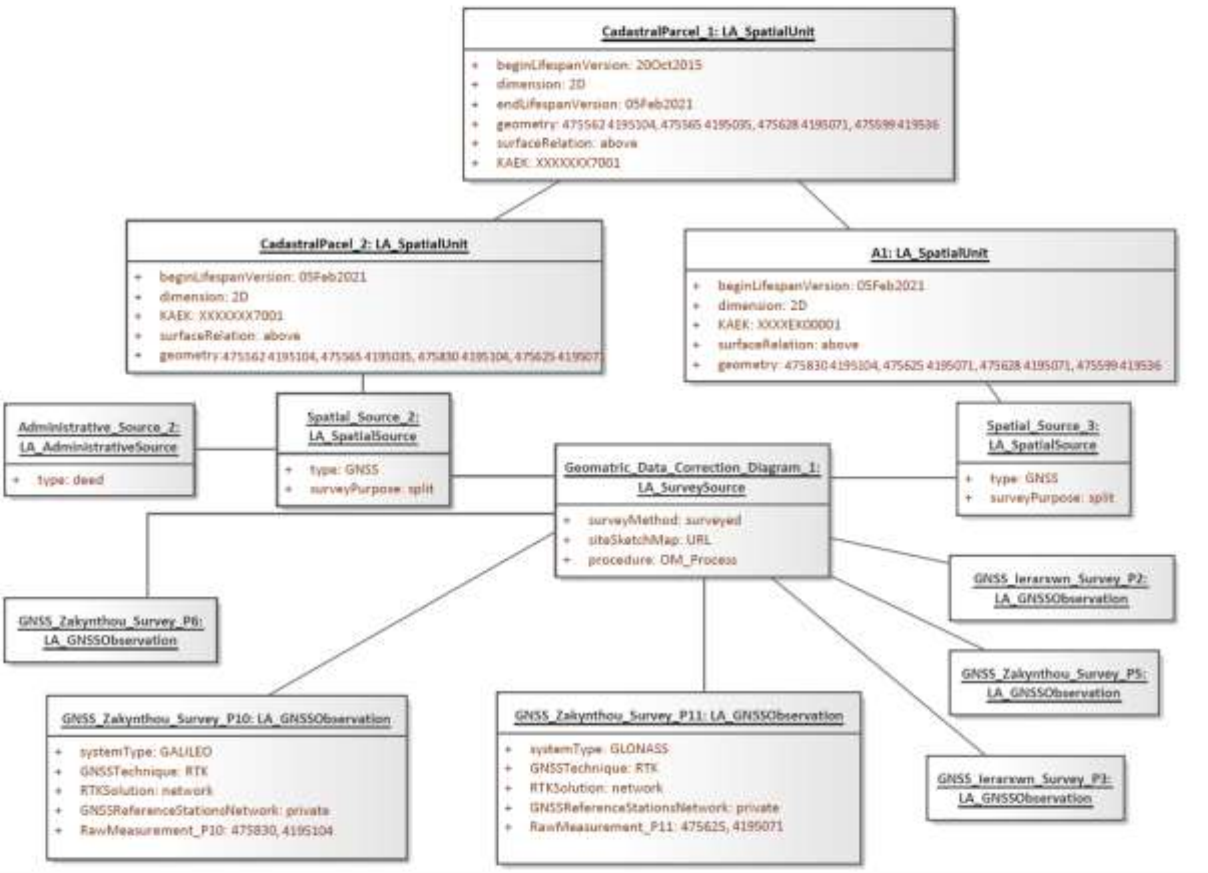

Figure 20. Instance level diagram of the Greek use case after split

6. CONCLUSIONS AND FUTURE WORK

The paper discusses the synergy between the LADM and the LandInfra standard, in the surveying domain, in the context of LADM revision. An overview of the current editions of both standards is presented, in line with their surveying functionality. Similarities and overlaps on some parts (i.e. Survey, LandDivision, Condominium) are identified, whereas the discrepancies on the scope and the level of detail on the modelling are highlighted.

The results of this paper contain work in progress towards the development of Part II of LADM Edition II, Land Registration, being part of the refinements of existing parts of LADM Edition I. To support a comprehensive spatial description, which incorporates the diverse elements of the survey module and specifically the 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 proposed.

In this direction, LADM will benefit from the detailed 'Survey' component of the OGC LandInfra and facilitate the interoperability among the two standards. The proposed conceptual Refined Survey Model includes several new classes, related to the various observation types that LADM Edition II will support, i.e. GNSS, Total Station, Image-based, point clouds, etc., the corresponding code lists that were needed, as well as new attributes on existing classes. Concepts of LandInfra 'Survey' part are incorporated in the proposed model, in a simpler way, to meet the requirements of LADM Edition II. Specifically, LandInfra contains much information about surveying equipment and set-up, and metadata about that, information that is not included in the proposed model, as it is not needed. Instead, a link to the corresponding LandInfra observation(s) where such information is stored is provided.

The development of the proposed model was informed by two case studies, from Denmark and Greece. For both countries, a description of the surveying workflow process followed is presented. The Danish case refers to the surveying part of a subdivision process, while the Hellenic case refers to the cadastral update process of a parcel subdivision and space concession. The new model aims to serve the surveying processes' needs for different countries and model efficiently the components of such countries.

Future work should include the investigation of a wider number of countries' surveying processes, including also developing countries where other approaches, such as participatory surveying are implemented (recent work from Morales et al. (2021) will be considered), and conclude to a generic workflow from the field to the cadastral office that can be used internationally. Based on that and the feedback from surveying experts of the international community, the Refined Survey Model will be further improved. This also refers to the LA_GalileoHAS class, where input from experts will be included, as it is expected that such services will support large scale cadastral updates and corrections to areas that need to improve the existing cadastral map accuracy. What is more, next steps include further refinement of LADM by incorporating LandInfra's aspects from other parts, especially LandDivision and Condominium.

Moreover, the connectivity between LADM and the International Land Measurement Standard, which sets out a structure for describing and reporting relevant land information for land transaction purposes, shall be also examined and where needed, new concepts and components to be added at the LADM Refined Survey Model.

Acknowledgements

This publication is part of the project GISCAD-OV that has received funding from the European GNSS Agency under the European Union's Horizon 2020 research and innovation programme under grant agreement No. 870231. The authors would also like to acknowledge Dr Panagiotis Lolonis, Head of the Geospatial Information Department and the Hellenic Cadastre for their support, and for providing data regarding the Greek case study, presented in Section 5.2.

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