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Key words: Public Law Restrictions, standardisation, LADM, 3D Cadastre, code lists

SUMMARY

Legal relations applying to land are of significant importance for land administration. Such relations include Rights, Restrictions and Responsibilities, deriving both from Private and Public Law. However, only the former are normally registered within cadastral systems, while the latter are either not required to be registered, or are registered to individual, thematic registries. Restrictions deriving from Public Law are gradually increasing in number and complexity, and impose significant impacts on land management, thus introducing the need of systematically organising and registering them. Standardisation is considered a means of fulfilling this aim, as it provides a common framework within which, consensus among different stakeholders on a specific process or product is achieved. Within the field of land administration, the international Land Administration Domain Model (LADM) standard plays predominant role in standardising legal relations between beneficiaries and land parcels. Therefore, this paper aims to investigate the integration of Public Law Restrictions' (PLRs) requirements, within the LADM context. As a first step, the PLRs are recognised and classified. Next, in relation to modelling based on LADM concept, three approaches are considered: 1. within the Administrative Package by adding subclasses for PLRs to the LA_Restriction class, 2. within the SpatialUnit Package by adding new specialisations and subclasses to the LA_SpatialUnit class (also extending the code list LA_RestrictionType with PLR types) and 3. again within the SpatialUnit Package, but by using the "level" concept of LADM and the class LA_Level (also extending the code list LA_RestrictionType). The different modelling approaches are identified and presented considering modelling efficiency, UML models' complexity and extensibility, while the proposed modelling approach can be considered for further extending and refining the current LADM legal concept, to include PLRs in the context of its revision. After initial considerations, such as model clarity, completeness, but also model simplicity, the authors opted for the third approach, as the one that best fits the purpose of PLR standardisation, which is then further analysed in more detail. Challenges regarding standardisation of PLRs within the LADM context, are also addressed, with regards to the on-going LADM revision process.

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1. INTRODUCTION

Modern Land Administration Systems (LAS) need to be based on the legal relations between beneficiaries and land parcels through land related Rights Restrictions and Responsibilities (RRRs) (Henssen, 1995). Such RRRs derive both from Private and Public Law, although mainly the former are included in cadastral registries. Public Law-related RRRs, are much greater in number, compared to those deriving from Private Law, and are also characterised by high level of complexity. Given the impact of Public Law on Land Administration, the need of systematically organising and registering potential restrictions has emerged. To this aim, organisation of PLRs within a standardised context is required to assist land management.

Depending on jurisdiction, legal systems stipulate ownership right or freehold tenure, to be the strongest right on land, that can be acquired by a beneficiary. The holder of such right has ultimate power on real property, as long as such power does not contradict to the Law or does not inhibit the rights of other right holders. Such stipulations can be traced on Property Law provisions of several jurisdictions, like the Dutch Civil Code (art. 5.1), French Civil Code (art. 544), German Civil Code (art. 903) and the Greek Civil Code (art. 1000). Provisions on not inhibiting others' rights fall into the field of Neighbour Law, while further restrictions are imposed by Public Law, within different contexts, such as state interventionism, economic regulations, serving of public interest, or national protection purposes (Georgiadis, 2012). Such restrictions, known as Public Law Restrictions (PLRs), impact on a great variety of fields, covering most contemporary human activities; to name a few: spatial and urban planning, archaeology, environmental and forest protection, water protection and groundwater, infrastructures, utility networks and infrastructure facilities, mining activities, aviation, etc.

Public Law pertains of several branches that affect land and real property management, such as environmental or administrative law and may extend both to urban and rural environment. The last decade, due to the multi-level exploitation and stratification of real property, the number of PLRs has grown rapidly (Kitsakis and Dimopoulou, 2016). Indicatively, Givord (2012) numbered 150 laws, ordinances and legislative arrangements regulating contemporary life issues in Switzerland, while Bennet et al. (2006) identified 620 Acts creating interests over land in Victoria, Australia.

Apart from their planar extent, PLRs also imply vertical restrictions, for example height or depth restrictions on land exploitation. Such restrictions can be explicitly defined in 3D (in terms of height, depth or volume), they may apply to 3D space, but with reference to non-geometrical characteristics (such as soil or hydrological characteristics), or they may be implied (for example, in case of landscape protection regulations), based on qualitative characteristics (Kitsakis and Papageorgaki, 2017; Kitsakis and Dimopoulou, 2018).

The last decades, urban areas are constituting a very dense and complex fabric of overlapping rights and restrictions, deriving from a significant number of overlapping and interlocking structures and utilities on, above and below the earth's surface. In order to secure public benefit interests, administrative authorities impose PLRs for various purposes, that may include public health and safety, environment protection (which covers natural, biological, socio-economic environment, as well as cultural heritage), while further restrictions are introduced, deriving from recent technological advances, such as restrictions on the flights of Unmanned Air Vehicles (UAV) (Kitsakis and Dimopoulou, 2016; Kitsakis and Dimopoulou, 2018).

Rural environment PLRs refer to cross-parcel infrastructure networks, such as powerlines or communication networks, where limited real property rights restricting surface parcel owners' rights are established, e.g. utility or public servitudes and rights of way, to allow for the construction, repairing and maintenance of the above-mentioned networks. These are mostly related to Private Law relations between the owners of the surface parcels and the owners or the administrators of each utility network, as registered on national cadastral systems. However, there is a significant number of other PLRs on land that cannot be established by instruments of Private Law (limited real rights).

Each jurisdiction addresses the issue of PLRs recording differently, using specific registries (Themed Cadastres), or incorporating specific types of PLRs to the cadastral registries (e.g. The Netherlands). Alternatively, Switzerland followed an innovative approach, establishing a centralised registry of PLRs in 2014. Currently, information about the most important public law restrictions on land ownership, deriving from federal and cantonal laws, is provided by PLR cadastres, which operate in eight Swiss cantons, while the establishment of PLR cadastres in the rest of the Swiss cantons is anticipated by 2020 (Swisstopo, 2015).

Given this background, there is need to efficiently model and organise PLRs and their related information. PLRs registration should be compatible with cadastral registries in order to enable information exchange, information integration and overlay with cadastral data. Using international standards for modelling PLRs allows for efficient identification and mapping of the whole of objects, transactions, relationships between objects and persons, classification of land use, land value, map representations of objects, etc. Currently, standardisation is limited to the region or jurisdiction level, while open markets, globalisation, effective and efficient development and maintenance of flexible systems, require further standardisation (ISO 19152, 2012).

In the context of this paper, the need to standardise PLRs according to international standards is addressed, to enable domain semantics to be shared between regions, or countries. Precisely, the international Land Administration Domain Model standard (ISO 19152, 2012), as a generic domain model, yet expandable, is proposed to be used as basis for PLRs standardisation. LADM provides an abstract, conceptual schema which enables the combining of land administration information from different sources in a coherent manner and provides standardised terminology enhancing interoperability between information systems. The standard is capable of supporting the progressive improvement of land administration and can potentially be used to support organisational integration, for example, between often disparate land registry and cadastral agencies. Currently, LADM is under revision and at the second edition of the standard, its scope will be extended, while parts of the current conceptual model will be improved.

The rest of the paper is structured as following: Section 2 presents a review on PLRs' registration and PLRs' standardisation approaches within the context of LADM. Following, the methodological approach is presented, including: (i) criteria that are involved in PLRs' classification and categorisation to be used within the context of this paper; (ii) investigation of the modelling approaches based on the LADM; and (iii) the proposed modelling approach. Conclusively, Section 4 discusses the results of this research and future work.

2. RELATED WORK

The following Section provides a review of the efforts to register PLRs over the last years, presenting qualitative and quantitative information regarding their type, characteristics and registration method. What is more, recent work on standardisation of PLRs within the context of ISO 19152 LADM is presented.

2.1 Review on PLRs Registration

The need of recording PLRs was highlighted by visionary work Cadastre 2014, so that the complete legal situation of land parcel could be defined (Kaufmann and Steudler, 1998), while it is acknowledged by national authorities of several countries globally, and it is also prescribed in legislation, e.g. CLRKEN Questionnaire (2015), Queensland's Environmental Offsets Regulation (2014). Depending on jurisdiction, the number, the type and the registry where PLRs are maintained vary. In the Netherlands, constructions that are destined to serve public benefit, such as power-lines or cables, monuments, and contaminated soil are required to be registered to the cadastre (Stoter and van Oosterom, 2006). The most prevalent approach on PLR recording, entails the establishment of themed cadastres, where specific types of objects are registered. Characteristic examples of theme cadastres are archaeological cadastres and utility cadastres. Figure 1, presents the types of the most commonly registered PLRs in Europe. Themed cadastres can be regarded to be partially recording PLRs, as they emphasise more on recorded objects than on the restrictions imposed on real property (Kitsakis and Dimopoulou, 2016). In most cases, registered restrictions apply to the surface parcels as a whole; therefore, the exact space where a restriction is imposed cannot be directly defined. Besides, even in case of a PLR accurately delimited in a horizontal plane, its vertical extent can only be traced descriptively in legal documentation. Consequently, it cannot be interrelated with other types of PLRs to identify the complete legal situation within a specific region or land parcel (Stoter and van Oosterom, 2006; Kitsakis and Dimopoulou, 2018).

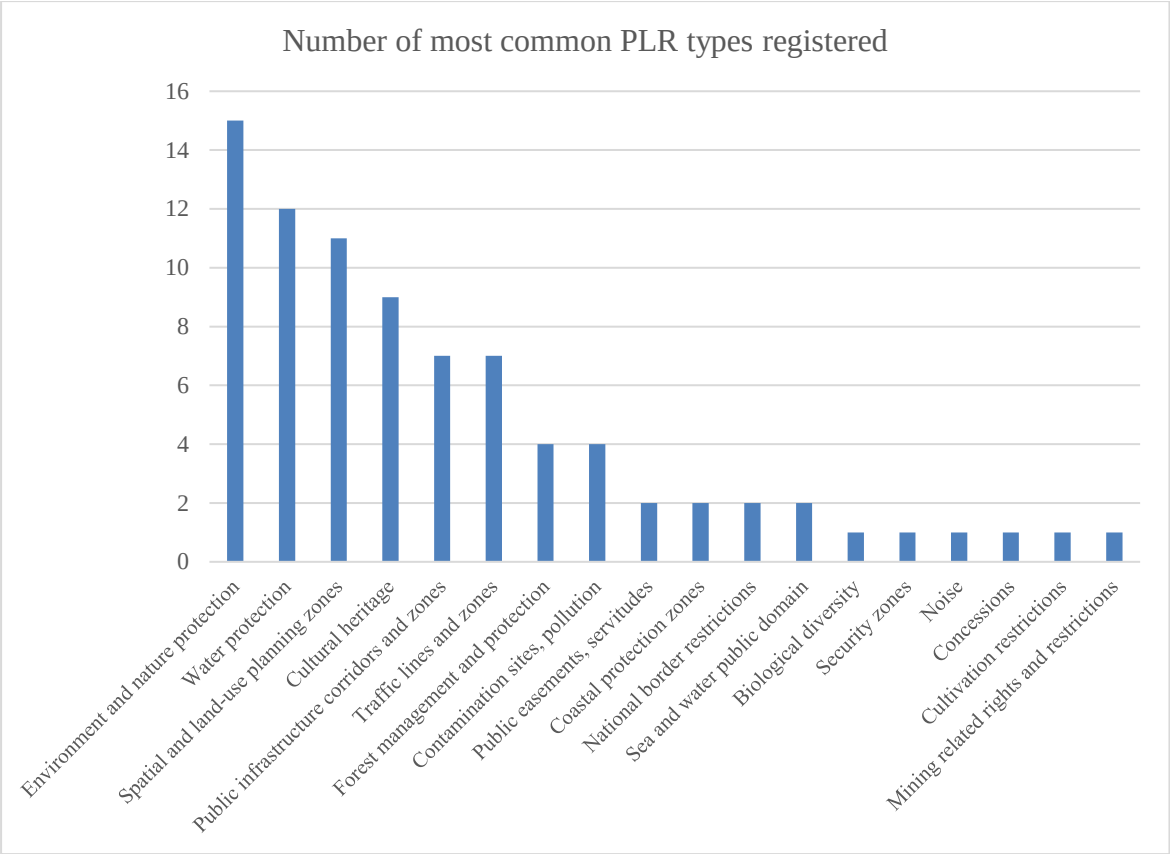

Figure 1. Number of PLRs' types registered in Europe (Adjusted, CLRKEN Questionnaire, 2015)

Regardless of the disadvantages of themed cadastres as a means of holistic presentation of the complete legal situation on land, they constitute a first step towards integration of Private and Public Law RRRs. Cartographic background of themed cadastres is based on cadastral background and, in several cases, themed cadastre registries allow theme data objects to be overlaid to cadastral parcels (Figure 2).

In order to create a complete and systematic record of PLRs applying to land, Federal Assembly of the Swiss Confederation (2007), established the Cadastre of Public-Law Restrictions on landownership (art. 16). Provision for the documentation of Public-Law restrictions with geometrical characteristics has also been introduced in article 57 of the Law on official surveying of the Principality of Liechtenstein (Kaufmann, 2015), while Land Cadastre Act of Estonia (art. 12) stipulates that objects giving rise to restrictions shall be registered on the restrictions map (RIS) (Kuus, 2011).

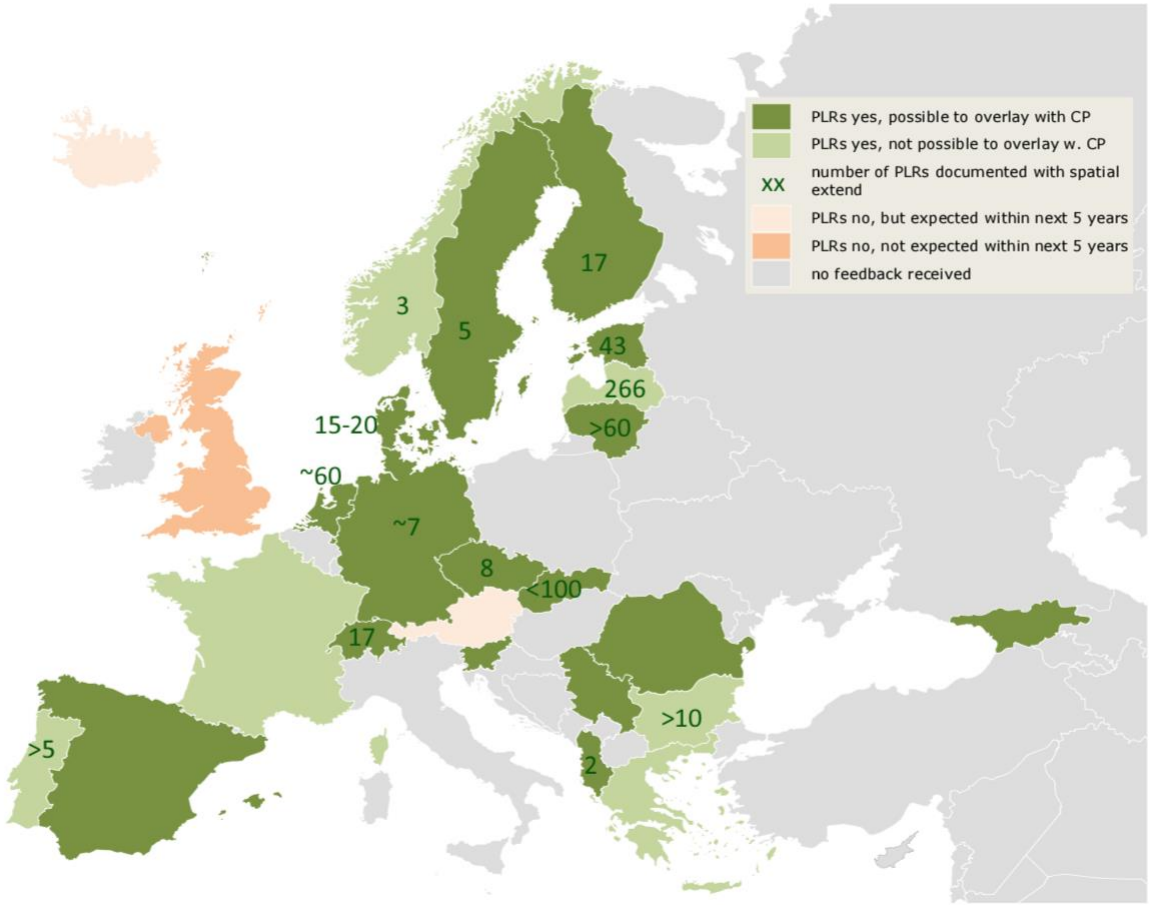

Figure 2. Documentation of PLRs and possibility of overlay with cadastral land ownership parcels (CLRKEN Questionnaire, 2015).

Swiss PLR Cadastre is established in each canton, which holds responsibility for their maintenance, jointly managed with the federal government. Strategic orientation and overall supervision of PLR Cadastres are under the responsibility of the Swiss Confederation (Federal Act on GeoInformation, 2007, art. 34). Swiss PLR Cadastres record seventeen (17) PLRs, classified in eight (8) sectors (Table 1) (Swisstopo, 2015).

Sector	Restrictions
Contaminated sites	- Cadastre of contaminated sites - Cadastre of contaminated military sites - Cadastre of contaminated sites at civil airfields - Cadastre of public transport contaminated sites
Railways	- Project planning zones for railways - Building lines for railways
Airports	- Project planning zones for airports

Sector	Restrictions
	- Building lines for airports - Security zone plan
Groundwater protection	- Groundwater protection zones - Groundwater protection area
Noise	- Noise sensitivity levels (in land-use zones)
Motorways	- Project planning zones for motorways - Building lines for motorways
Spatial Planning	- Land-use planning (cantonal/municipal)
Forests	- Forest perimeters (in building zones) - Forest distance lines

Table 1. Classification of PLRs registered to Swiss PLR Cadastres (based on Swisstopo, 2015).

Swiss PLR Cadastre data are available in dynamic (via cantonal geoportals) or static (as official PDF documents) form (Swisstopo, 2015) and consist of (Barbieri, 2015):

- The legal provisions that impose restrictions on land and the effects of such restrictions.
- A map depicting the region where PLRs apply.
- The general regulations on which rulings are based.
- Additional information.

An example of the PLR Cadastre of the canton of Bern is presented in Figure 3.

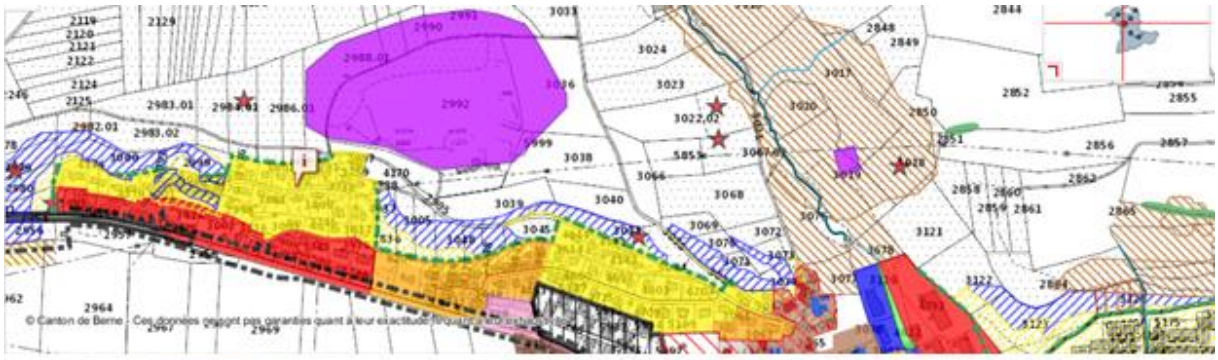

Figure 3. Top: PLR Cadastre map of the canton of Bern showing the areas where PLRs in different colours. Bottom: Link to statutes imposing PLRs (Canton of Bern Geoportal, 2018).

2.2 Review on standardisation of PLRs

The extension of the cadastral systems with Public Law Restrictions aims to make the land market more transparent, and therefore more secure. For that reason, the last decades the documentation and registration of PLRs, is increasingly becoming an issue in several countries globally. However, this activity is still in its early steps, as the enactment of a PLR is influenced by societal changes, economic needs, demographic data, environmental factors as well as other

parameters (e.g. archaeological excavations) (CLRKEN Questionnaire, 2015). Standardisation in this domain is a challenge, but at the same time an urgent need to enhance information sharing, information integration and interoperability.

Setting the scene at the international level, the Land Administration Domain Model is a generic domain model describing "people to land" relations through the Rights, Restrictions and Responsibilities (RRRs). The standard is expandable, to support additional attributes, operators, associations, and even additional classes that may be needed for a specific region or country (ISO 19152, 2012). At the current edition of LADM, specific parts are further modelled and included in the informative Annexes. Specifically, in Annex F, a further modelling of the Rights, Restrictions and Responsibilities is presented through three legal profiles: a legal profile for rights, a legal profile for restrictions and a legal profile for responsibilities. A legal profile is a profile with elements from the LADM Administrative Package and from the Party Package providing a refined modelling of those elements. Figure 4 illustrates the LADM legal profile for restrictions.

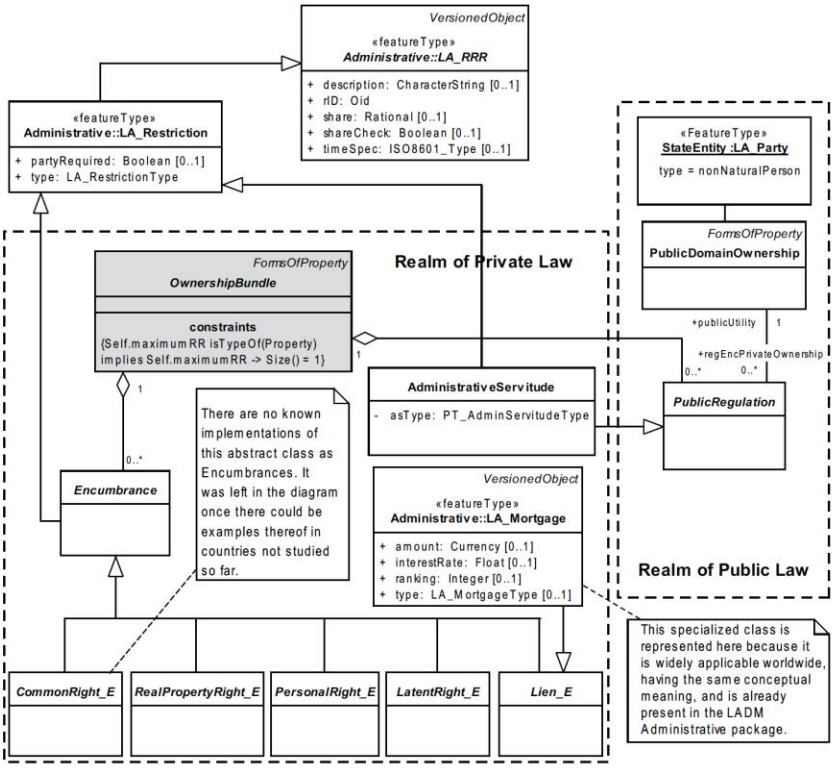

Figure 4. LADM Legal Profile for restrictions [ISO 19152 - Fig. F2, 2012]

Paasch et al. (2013a, 2013b) proposed a more detailed, standardised classification of RRRs than in the current edition of the LADM. They suggested a classification of private and public interests to be implemented in the LADM administrative package on a conceptual level, according to the Legal Cadastral Domain Model (LCDM) as developed by Paasch (2012). Particularly, the authors proposed specialisations for the LADM classes LA_RRR, LA_Restriction, LA_Responsibility for the realm of public law and private law accordingly. Figure 5 illustrates the proposed extended profile for the restrictions. Considering PLRs, a new

class is created "LA_PublicRestriction" and it contains the "*Public regulations creating a prohibition for the real property owner to perform certain activities on his/her real property*". Furthermore, the public restrictions can, as described in the LCDM (Paasch, 2012), be divided into general and specific types and therefore, as "Public general restrictions" are considered the regulations prohibiting or mandating activities on certain types of real property at a general or specific level. The public general restrictions are modelled at class level and therefore a new abstract class "LA_PublicGeneralRestriction" was introduced (Figure 5). The code lists for the "LA_PublicGeneralRestriction" class is considered as explicit representation of the relevant generic public legal items.

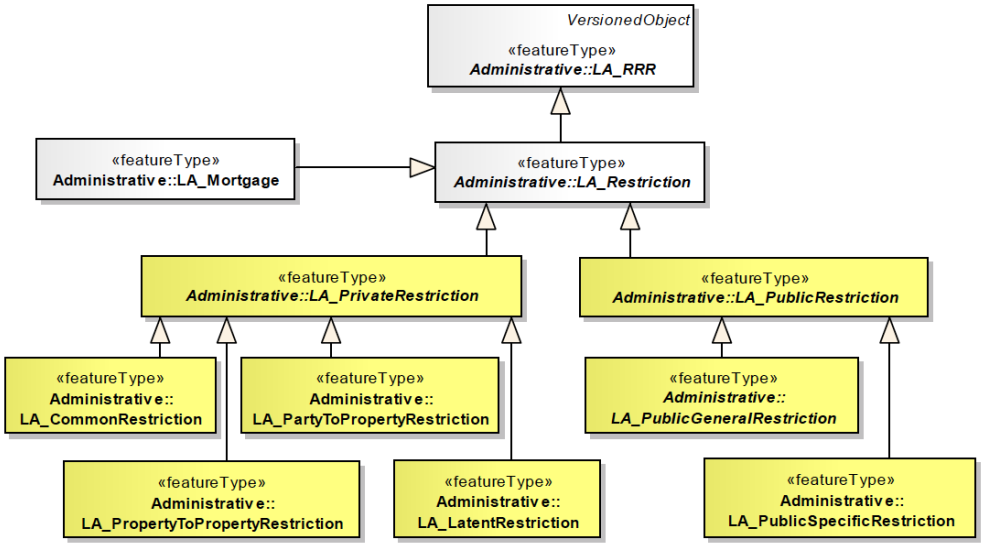

Figure 5. Specialisation of the LADM LA_Restriction legal profile. Extended profile for privately and publicly imposed restrictions [Paasch et al., 2013a]

Moreover, based on the proposed extended classifications of the LADM RRR class as presented by Paasch et al. (2013a) and Paasch et al. (2013b), the same authors (Paasch et al., 2015) further discussed the informal rights in terms of LADM and they proposed specialisation of LADM code lists, using the Legal Cadastral Domain Model and the Social Tenure Domain Model, to represent RRRs on a more detailed level, including informal rights, restrictions and responsibilities.

The authors conclude that instead of adding refined classes at the administrative part of the model (that may better define the types of tenure), it is more appropriate to enrich the standard at a content level by adding relevant code lists of RRRs types. According to the authors - and considering the most appropriate modelling approach for this case- there are no differences identified in the structure of the different types of RRRs; for instance, different attributes, properties of relationships. It is better to consider adding new code list values rather than adding more classes that will be quite similar to each other and will make the UML model more complex. Within this context, they also proposed a hierarchical structure for the code lists and organised them into various levels, while introducing an ontology of interests in land, water and air (Figure 6). The ontology shows that there are two types of interests in land: formal interest and informal interest, which can be divided into publicly or privately executed interests. The interests in land can be further subdivided in rights (blue circle), restrictions (orange circle) and

responsibilities (purple circle), while examples from the LADM code lists in Annex J of ISO (19152:2012) (ISO, 2012) are added to the diagram as examples of RRRs (Paasch et al., 2015).

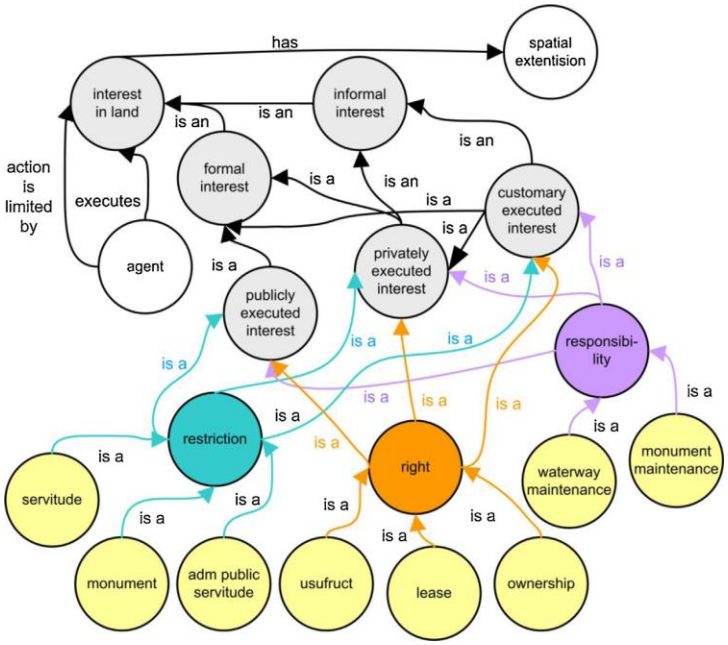

Figure 6. Ontology diagram showing land use relations, exemplified with RRRs listed in LADM Annex J of ISO (19152:2012) [Paasch et al., 2015]

3. METHODOLOGY

In this Section, the methodology followed in the context of this research is provided. As a first step, in order to efficiently categorise the different types of PLRs that are usually found in different jurisdictions around the world, it is crucial to observe the various aspects that may affect their classification. Therefore, the criteria that are involved in PLRs' classification are discussed, and the categorisation is based on the work of Kitsakis and Dimopoulou (2016). Since aforementioned work was focusing on 3D PLRs, it has been adjusted accordingly, so that the whole range of land-related PLRs are incorporated. Categorisation was based on international literature research on Public Law Restrictions, emphasising on the Greek legal framework, also considering the categorisation that is implemented for the Swiss PLR Cadastre. In the next step, the modelling approaches offered within the context of LADM are investigated and compared. Finally, the approach that best fits the purpose of this paper is further analysed and graphically represented via a UML model.

3.1 Classification of PLRs

To efficiently organise the different types of PLRs, it is important to observe the aspects that are involved in their categorisation. From legal perspective, PLRs can be classified according to the branch of Public Law they pertain to, such as constitutional or administrative law. Alternatively, PLRs can be classified based on their purpose; for instance, restrictions serving

national security, public health, urban planning, social and public policy, environment protection etc.
Another aspect that can be considered for the classification of PLRs is referred to the different thematic fields where PLRs are pertained, such as cultural heritage, or urban planning legislation. Each class of this type of classification includes restrictions of both primary and subordinate legislation related to each thematic field, while more than one set of laws, regulations, ordinances or decrees may be included within a single field. For example, within the collective term of water legislation, statutes related to surface waters and groundwater bodies are included.
The latter classification option is preferred in order to avoid exhaustive inclusion of the abundance of land-related PLRs that would result in highly complex and non-functional (in terms of technical capacity and cost-effectiveness requirements) structures. The proposed PLRs modelling approach is based on the classification by Kitsakis and Dimopoulou (2016) and it was adjusted to fit in the context of this work, as presented in Table 2.

Category of PLRs	Description
Mining areas	- State-owned, landowner minerals - Oil and gas - Health and safety provisions
Cultural Heritage	- Restrictions regarding in-situ preservation of antiquities - Restrictions to avoid harm of underground antiquities (due to construction of infrastructures or other activities) - Restrictions in constructing new buildings, alteration, restoration and use - Restrictions in maritime activities within or in the vicinity of marine antiquities
Landscape	- Restrictions on building height for landscape protection. - Restrictions on materials, scale, colour, size, architectural style of constructions to match surrounding landscape.
Soil	- Restrictions regarding soil contamination (deriving from soil geological or chemical characteristics) - Mitigation measures on contaminated soil
Water	- Surface water - Groundwater bodies
Air	- Restrictions for the protection of public health from contaminants on air. - Restrictions regarding radio waves propagation to ensure efficient communication and broadcasting as well as protect public health and natural environment from extended exposure to electromagnetic fields. - Restrictions regarding public exposure to electric and magnetic fields due to the installation of antennas.

Category of PLRs	Description
Noise	Restrictions on zones of noise propagation and vibration
Natural protection zones	- Forest - Natural habitats - Biodiversity - Protected areas
Civil Aviation	- Non-military manned air vehicles (e.g. Definition of special flights' rules such as non-flight zones; Definition of general minimum flight height; Definition of Obstacle Limitation Surfaces, designating the airspace around an airport where restrictions apply to constructions' or physical objects' heights) - Unmanned Air Vehicles (e.g. Fly under permission above specific heights; Flight prohibition over infrastructures or correctional facilities; Definition of maximum flight height)
Spatial Planning	- Construction Regulations - Shoreline and coastal zones
Public utility networks	- Land use restrictions - rights of way - servitudes of passage
Major infrastructures	- Land use restrictions - Rights of way - Servitudes of passage
Military zones	- Restricted areas - No flight zones

Table 2. Classification of PLR in categories (adjusted, Kitsakis and Dimopoulou, 2016)

As mentioned above, selected categories included at the proposed PLR classification are collective and may be further sub-categorised, depending on each jurisdiction's legal specifications. Within this context, Cultural Heritage PLRs include restrictions related to terrestrial and maritime archaeological sites, monuments, or areas of intangible cultural heritage. This applies also in case of Water PLRs (incorporating restrictions on surface and groundwater bodies), PLRs related to Natural Protection Zones and Spatial Planning, which incorporate restrictions that can be traced in legal statutes of different fields (e.g. forest protection restrictions and restrictions for the protection of natural habitats are, inter alia, classified within Nature Protection Zones category), etc.

As concluded by Table 2, each PLR category is defined by referencing various characteristics of qualitative or quantitative nature. The former includes non-measurable criteria, which, in most cases, are objectively defined. Restrictions regarding landscape protection are among the most common qualitatively-based PLRs. On the other hand, quantitative characteristics can be mathematically measured and defined, by reference to their spatial extent, physical or chemical attributes, concentration of contaminants. However, neither all types of quantitative PLRs are

directly definable in space, nor is their spatial extent defined in 3D space. Some of them are directly defined by reference to the horizontal and/or vertical extent of a restriction, while others refer to the physical or chemical characteristics that apply to a region.
This introduces the need to explicitly define PLRs in 3D terms and map them in 3D space. Most commonly, PLRs are presented as horizontal plane projections, while their vertical extent may be literally described in corresponding legal documentation; thus, the exact extent of a restriction cannot be unambiguously defined, nor can it be spatially interrelated with other PLRs within the area. Regarding the restrictions based on physical, chemical or other non-geometrical characteristics, these need to be translated in terms of height, depth or volume; for instance, the depth of a liquefiable soil stratum, or the volume of contaminated groundwater. However, more complex non-geometrical characteristics may occur, for example in case of air pollution dispersion (where parameters such as humidity, wind speed, or mixing height are involved), or sediment entrainment, which are more challenging in terms of "translation" to height, depth or volumetric restrictions.

3.2 Investigating PLRs Standardisation Alternatives

Previous sections presented the background for organising and modelling PLRs within the context of international standards and specifically the LADM. In the following paragraphs, standardisation alternatives for modelling PLRs are investigated and compared, in terms of modelling efficiency, UML models' complexity and extensibility. The core question that need to be answered when modelling those restrictions is:
Should all the instances of PLRs be explicitly be recorded (area/location and involved parties), or merely the rule that they follow? In the latter case, other spatial data could be used (via the SDI) to figure out the specific locations; e.g. in the Land Administration model/registration just the rule is stored 'within 50 meters of the kerosene pipeline no construction or digging is allowed', then by using the geometries from the cable and pipeline registration all kerosene pipes in country are selected and buffer of 50 meters is applied to figure out which areas are restricted. In this context, and as stated in Section 2, there are two main approaches that may be followed: at level class or at instance (content) level. In order to avoid legal uncertainty, it was decided to follow the approach to register explicitly all instances of the PLRs (with their location and involved parties). Next step is to apply the LADM approach to cover the various types of PLRs, so that during implementation the instances can be properly represented. There are various options to apply/ extend the model; e.g. adding new classes as specialisations to the parent class, and/or by applying structures, such as code lists and/or the LA_Level concept, which are further modelled and enriched. Given this background, three alternative modelling approaches are identified towards PLRs' standardisation:

1. Further modelling, at class level, of the proposed extension of the legal profile for public restrictions, as described by Paasch et al. (2013a), with regards to the classification of PLRs presented in Table 2. In this case, the class LA_PublicGeneralRestriction can be specialised and subclasses for each of the PLRs type will be added at the Administrative Package of the model. Therefore, the PLR is directly attached to the content of the restrictions.
2. Further modelling, at class level, of the core LA_SpatialUnit class, by adding new specialisations and subclasses to it (similar to LA_LegalSpaceUtilityNetwork or LA_LegalSpaceBuildingUnit), therefore creating a new subclass for each one of the

PLR types described in Table 2. In this case, the object that is related to each PLR is associated with the spatial unit and not directly with the restriction (only the code list LA_RestrictionType is extended with the proper values).

3. Further modelling of the spatial unit package, at content level, using the "level" concept of LADM, with regards to the classification of PLRs presented in Table 2. The "LA_Level" class of the LADM Spatial Unit package defines "*a set of spatial units, with a geometric and/or topologic and/or thematic coherence. This concept is important for organising the spatial units in LADM*" (ISO 19152, 2012). It is important to note that the principle of legal independence is supported through this class, as the type of land register and different types of spatial units can be combined in one level. This allows for integrating data delivered by different organisations with different mandates and for integrating data based on different spatial units (Lemmen, 2012). Within this approach, structured directions of how to model each of the PLRs type are proposed, without adding more subclasses (that would make the model more complex). The code list LA_RestrictionType is extended with the proper values.

By choosing the first alternative, based on the class level modelling approach, new classes for the different types of PLRs will be added as specialisations of LA_PublicGeneralRestriction class. This approach will lead to exploit and clear model characteristics of the various PLR types with structured attributes and associations. However, multiple quite similar classes, (of non-concrete differences in terms of properties and relationships) will be added to the UML model, thus making it more complex. It is also even unclear if the different types of PLR's need different attributes (and/or associations) to be included in the model.

Moreover, the second alternative is similar to the first in terms of modelling. Class level modelling approach is used, and new subclasses will be added as specialisations to the "LA_SpatialUnit" class. The numerous, similar subclasses that will be added still increase the complexity of the UML model, however it seems more appropriate to model those restrictions in association to their spatial extent.

Lastly, the third approach, based on the content of LA_Level modelling, proposes the concept of a "modest route" needed no additional classes, but still providing a structured way of modelling instances that may occur more than one time. Characteristics related to the different PLRs types will be modelled, while it is easy to update or extend this structure using the "level" concept.

3.3 Proposed Modelling Approach

Within the aim of this paper, it is concluded to use the LA_Level modelling approach and connect the object/zone, on which a PLR is attached, to the spatial unit and not directly to the restriction (but indicate the type of PLR by adding new/more code list values of LA_RestrictionType). For instance, in case of a cultural heritage monument, that is registered in the monument register (with its own location, properties, etc.), a restriction may be imposed, which is represented in land administration via the spatial unit (in 2D or 3D) and therefore, through the associations between LA_SpatialUnit, LA_BAUnit and LA_RRR (and specifically, LA_Restriction), it is connected to the restrictions. Figure 7 presents the proposed LA_Level modelling approach. A note regarding the proposed Restrictions levels is presented and contains 12 levels, according to the PLRs types presented in Table 2. Apart from the restrictions' level,

a corresponding note with Rights level is presented in Figure 7; it is based on a proposed structure for modelling different spatial units' types and their characteristics, presented by Kalogianni (2015). The reason why those levels are also presented is because it is important to have both rights and restrictions that may apply to a spatial unit, as they are sometimes interrelated, while the use of the concept of "level" is considered a correct approach at the conceptual modelling level.

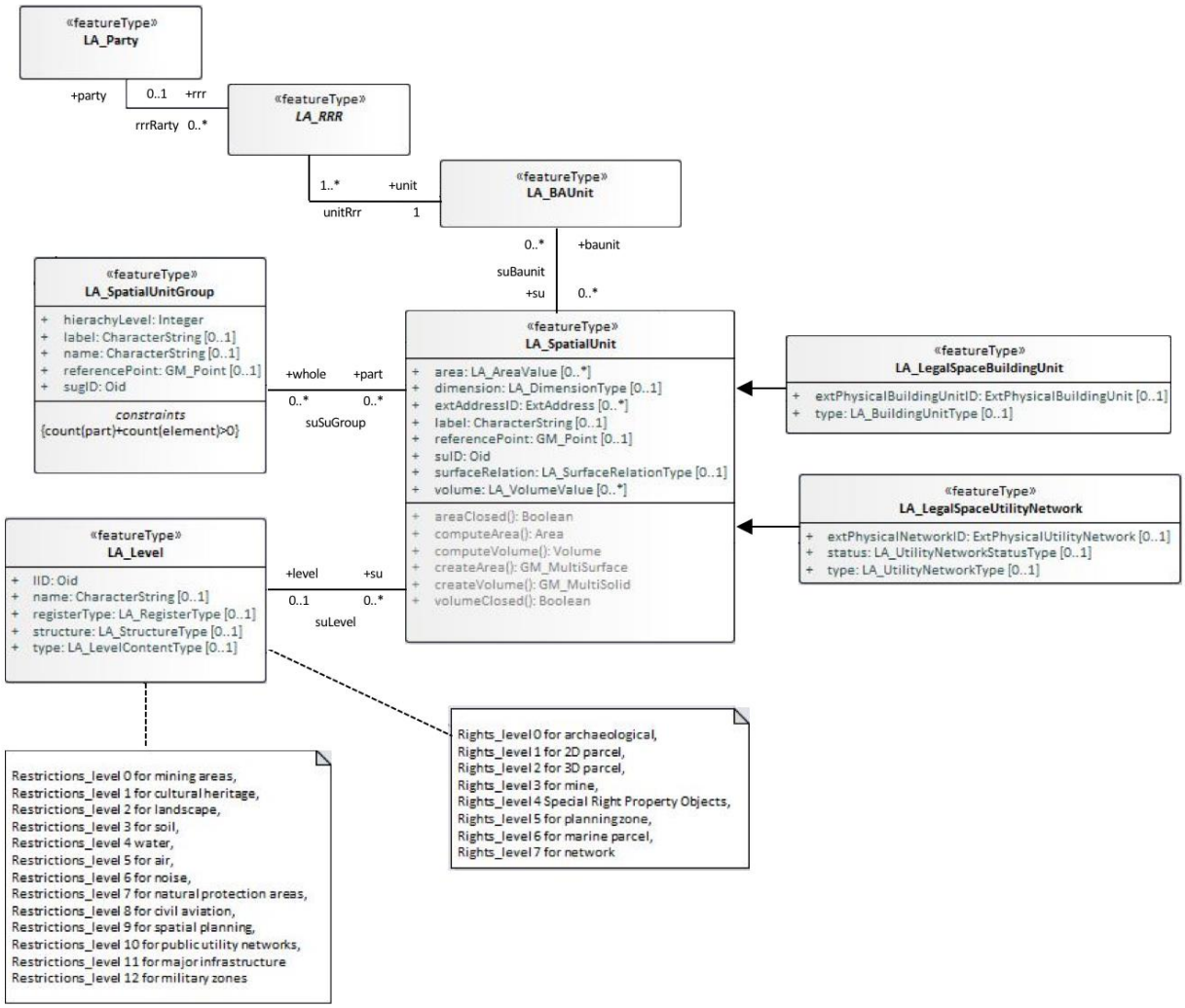

Figure 7. Proposed LA_Level modelling approach, restriction and right levels for PLRs

For the afore-mentioned modelling approach the LADM code list for LA_RestrictionType attribute is extended with restriction types for PLR's, as presented at Figure 8.

Figure 8. Proposed extended code list for LA_RestrictionType covering different PLR types

Figure 9 illustrates how the LA_SpatialUnit class is organised at the Restriction Level 4: water. It is noted that the attributes that are added at the LA_PLRwater class are exemplary, within a general context, and their implementation would require to be further adjusted according to national legislation/policies. Similarly applies to the exemplary attribute values: the value type "char" is selected, in a general context that may include qualitative or quantitative parameters, depending on national legal framework. As a future step, corresponding code lists for several of those attributes (e.g. groundwaterVulnerability) could be created.

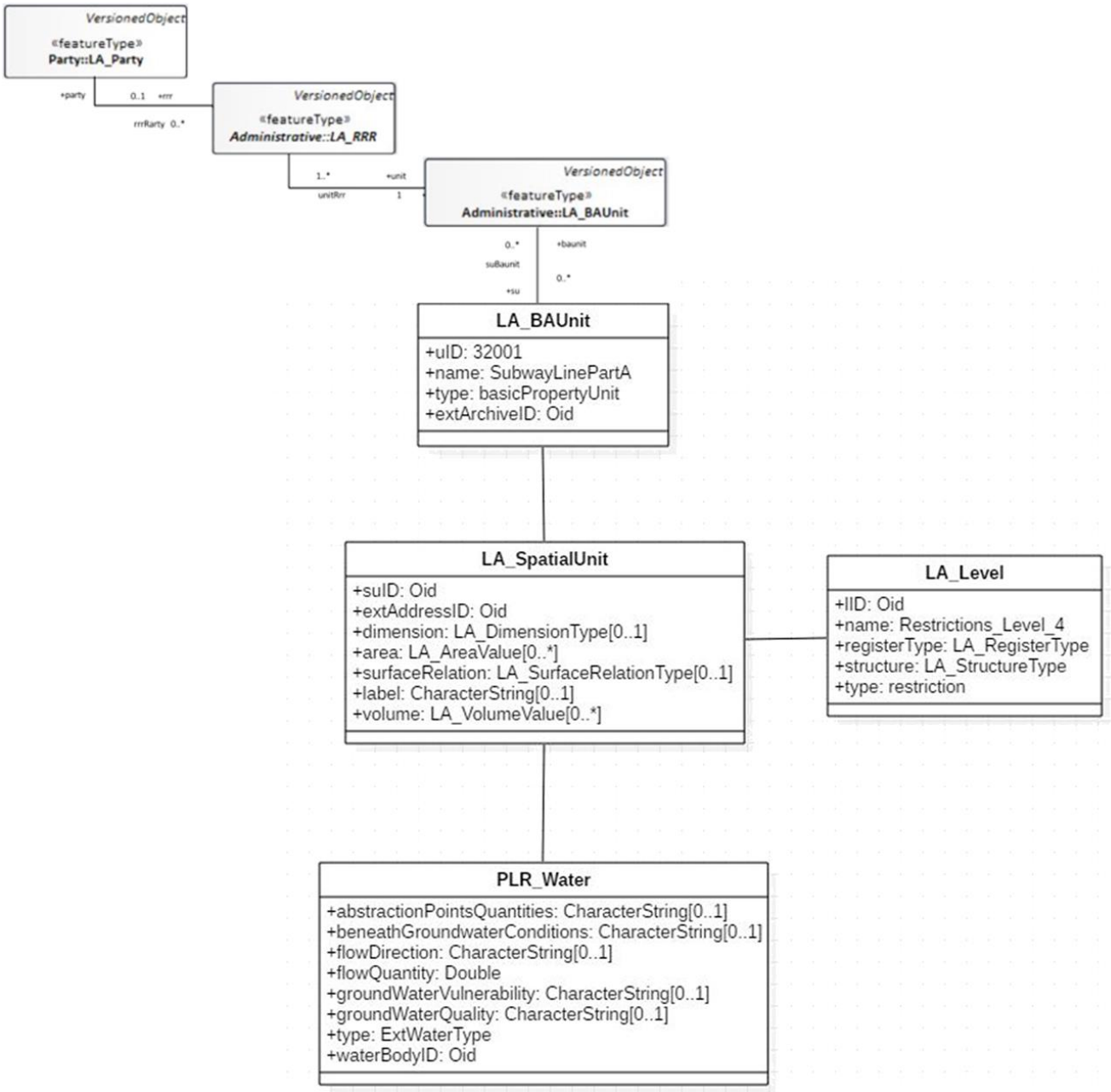

Figure 9. LA_SpatialUnit organised in Restriction_Level4: water, based on the proposed modelling approach and lined with the external register

In the context of Spatial Data Infrastructure, it is possible to connect external registries and databases with the land administration system, through external associations/links and therefore, the communication between the LADM classes and the registry, where the PLR is registered, can be achieved. In this case, an association with the external registry, including water bodies' related PLRs information may be added.

3.3 Implementation of the proposed modelling approach through a case study

The modelling approach proposed is examined through a case study referring to the ongoing project of the subway line in the city of Thessaloniki, Greece. Thessaloniki's archaeological and historical significance, along with its leading character in the region of Macedonia in Northern Greece, result in the need for stratified land exploitation, especially in the field of construction projects (Kitsakis and Dimopoulou, 2017).
Figure 10 illustrates the 3D representation of PLRs (left) and the existing cadastral and spatial data recordings (right), underlying the necessity of registering and visualising PLRs in 3D. At the current cadastral documentation, no reference is made to the archaeological restrictions imposed (that is registered as PLR level 1 at the proposed model). It is noted that in case of real property expropriation for archaeological purposes, registration of the related administrative acts is required.

Figure 10. (left) Exported 3D PLR model; (right) current cartographic documentation of the case study area as presented in the Thessaloniki municipality geoportal [Kitsakis and Dimopoulou, 2017].

Figure 11 presents the instance level diagram for the use case of archaeological restriction (PLR Cultural Heritage).

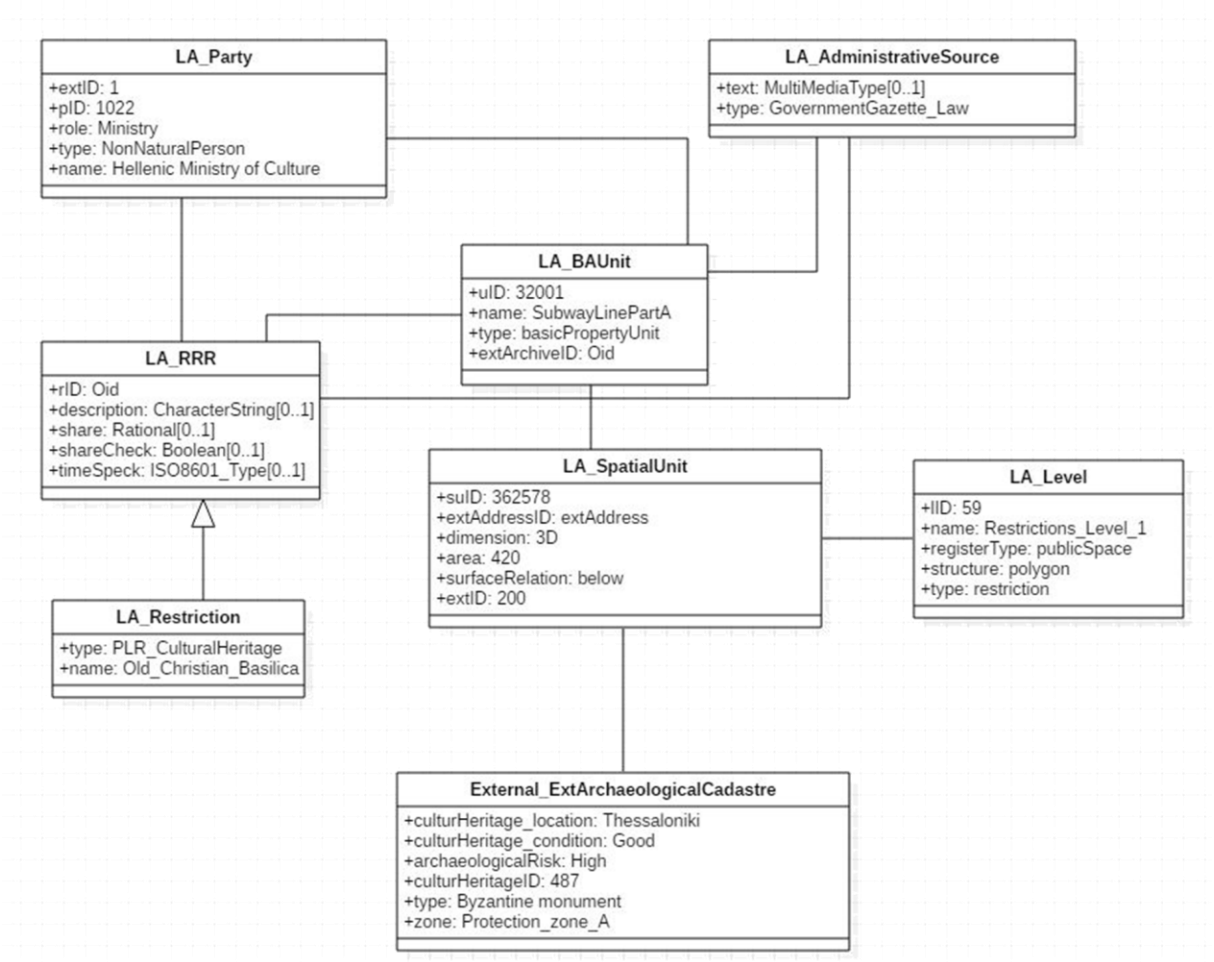

Figure 11. Instance level diagram for archaeological restriction use case (PLR Cultural Heritage) related to the subway line

4. DISCUSSION AND CONCLUSIONS

Incorporation of PLRs into a standardised framework is a challenging task that relates to legal, administrative and technical requirements. In this perspective, PLRs were identified and classified into categories to be supported by a standardised framework, considering various classification criteria (as presented in Section 3). The resulting different types of PLR categories, combined with the number, as well as the interrelation between the characteristics used to define a PLR, complicate the selection of the most suitable classification method. In this research work, the classification was based on thematic fields, considering the land-related fields of the Public Law branches. This is based on the specific type of classification that provides flexibility and can be modified according to national policies, thus resulting in different PLR categories. A second challenge relates with the definition of PLRs. Legal restrictions are in most cases descriptive, referring to their objective, e.g. prevent pollution or flooding, while more specific measures are defined in subordinate legislation. This introduces the need of defining qualitative characteristics in quantitative, spatial terms; this may also apply in case of quantitative, physical, mechanical or chemical characteristics that need to be defined

in spatial terms. Within this context, the third dimension needs to be considered, since most PLRs refer not only to the horizontal plane, but on 3D space as a whole. This relates to the inconsistency between the registries maintained to record PLRs (in jurisdictions where PLRs are registered), since such registries are structured in 2D, therefore they cannot support, potential, 3D defined PLRs. Definition of the space on which a PLR is imposed is also of importance within the context of PLR standardisation. Distinction is made between physical (covered by a structure) and legal (imaginary, non-materialised) space. Setting PLRs as the reference frame, such distinction needs to be enriched, as several PLRs are defined in other terms, for instance using geographical, geological, or hydraulic boundaries.

Given this background, alternative approaches for modelling PLRs based on international standardisation initiatives and specifically LADM are investigated, considered as basic modelling approaches to be identified and examined within the context of extending the standard. Their benefits and drawbacks were presented to conclude to the proposed approach at the content level, by connecting the object/zone, on which a PLR is attached, to the spatial unit and not directly to the restriction using the 'level' concept of LADM. This results to a proposal for structuring the different PLR types, without increasing the complexity of the UML. Since LADM is under revision, broadening its scope, the proposed modelling approach can be considered for further extending and refining the current LADM legal concept to include PLRs. As further steps, the corresponding classes for each one of the proposed levels will be created, including characteristics that derive from the statutes imposing and regulating PLRs. Links to external database registrations will be added to enable the communication with the registers that PLRs are (or will be) registered and relevant constraints enforced correct and strong associations between the LA and the external registry will be added. Furthermore, code lists for each one will be created including general values that may apply worldwide. It is proposed that the hierarchical structure of code lists as proposed by Paasch et al. (2015), will be used to structure and maintain the new code lists and facilitate their extension at national/jurisdiction level, thus, avoiding repetition. Adding more content and structure to the current code lists for the LADM Administrative Package would then be another step to consider during the LADM revision. Lastly, having completed the classes of the proposed levels regarding PLRs, an ontology can be created, illustrating the different types of PLRs and their code lists.

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