Toward a Croatian Utility Registration Implementation Model Based on LADM

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Keywords: Utility registration, Utility cadaster, Land Administration Domain Model, Conceptual modelling.

SUMMARY

This paper reviews approaches to utility registration and analyzes the Croatian utility cadaster and utility registration regulations. In Croatia, utility networks are registered in the national utility cadaster administered by State Geodetic Administration, with private companies obliged to send reports on all changes to the utility networks that they manage. The Croatian utility cadaster, besides data about managers and geometry of utility networks, registers various technical data about physical utilities. This paper then analyzes the land administration domain model (LADM) and LandInfra standards and their abilities to model both legal and physical features of utility networks that need to be registered in the Croatian utility cadaster. As some jurisdictions look on utility networks as separate legal objects that can be owned or leased, possibilities to model all attributes needed in the Croatian utility cadaster with an LADM-based model was further investigated. Finally, the paper proposes a utility registration implementation model based on LADM that can describe both physical and legal features of utility networks.

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1. INTRODUCTION

The idea of utility networks, or the concept of transporting certain resources needed by the public through the network system, dates to early stages of urbanization. Therefore, the first water distribution systems and plumbing networks can be traced to the Bronze age. Until the 19th century, gas was used almost only as a source of light, but with industrialization and inventions, such as Bunsen burners and internal combustion engines, the consumption of fossil fuel has significantly increased along with the need for their fast and efficient distribution. In the late 19th century, discoveries of alternating current and transformers enabled the long-distance distribution of electricity and the development of electric networks enabled the rise of another utility network, electronic communication.

Since the invention and the first historical occurrence of utility networks, their numbers have only risen through the years, aided by various inventions as well as population growth. Another factor is rapid urbanization after industrial revolution; it has led to fast growing cities and the need for a large number of utilities and buildings in a limited amount of space. With such growth, appropriate registration of these utility networks has lagged behind their development. In the beginning, utility networks were rarely registered, which created issues in conjunction with the management of utility networks, as well as frequent damages and accidents in the course of excavation works.

The relationship between humans and land dates back to the time when humanity switched to permanent settlements and agriculture. There is written evidence dating back to ancient Egypt and the valley of river Nile that shows that land was divided in parcels for the purpose of determining land ownership and taxation. Nowadays, with rapid urban development, population growth, and scarcity of space, appropriate administration of land is only more important than ever (Lemmens, 2011).

As mentioned before, for every organized society, land administration, and with it, the administration of attached constructions, such as utility networks, is essential. Nevertheless, every type of society can have different approaches for dealing the challenge. When it comes to utility administration, we have two different approaches: centralized and decentralized. In former communist countries, there is an authoritative approach with national frameworks and sets of laws regulating utility administration and utility cadasters on the national level, while in western countries, the responsibility for utility administration is on companies that own infrastructure, or in some cases, on local authorities (Roić, 2012).

In order to represent some physical phenomena, we first need to define the data models for the phenomena. The land administration domain model (LADM) is ISO standard focused on land administration, with few classes concerning utility networks. As mentioned earlier, land administration relates to land value, tenure, use, and development. LADM is mainly focused on tenure, or more precisely information about rights, responsibilities, and restrictions on land. Since 2017, initial ideas for creating the second edition of LADM have been proposed, with the intention for more complete support for spatial planning, valuation, and marine cadaster, and are closer to implementation (Lemmen et al., 2019).

In this study, we analyzed the possibilities of creating a utility registration implementation model based on LADM that would be able to describe data about the technical and legal characteristics of utility networks. Possibilities were analyzed against the needs and data registered in the utility cadaster in the Republic of Croatia by analyzing interactions with other related standards, mainly LandInfra.

2. METHODOLOGY

In this study, the Republic of Croatia was used as a use case study. The current state of the national utility cadaster, laws, and regulations was analyzed, and they were further formalized. Since the development of the national utility cadaster in Croatia was stagnant, mainly laws and the requirements of the utility cadaster were observed. Republics from former Yugoslavia were part of the eastern, or authoritative, approach to utility administration. Therefore, these countries passed the utility cadaster regulations on the national level. The utility cadaster regulations were concerned only about technical data, and they are missing the framework for legal relations on utilities, such as rights, restrictions, and responsibilities. Through the years, laws have been occasionally renewed and updated, but never fully implemented (Bulatović, 2011).

Secondly, international standards concerned with land administration and utilities were analyzed and compared, mainly the current state of the ISO standard LADM and its scope, as well as the OGC standard LandInfra. LADM is more concerned with the legal aspects of land administration, while LandInfra includes models for physical utilities.

As the final step, the laws and requirements of the utility cadaster were compared with those of the LADM model, with the proposal of a utility infrastructure implementation model based on LADM.

LADM edition I is a conceptual scheme focused on land administration. A conceptual scheme, or conceptual data model, is a representation of some system, e.g., infrastructure and interests on this infrastructure in the utility cadaster. It describes both the main concepts and the relationships between them. Edition II of LADM is in the making, and this version will be closer to implementation with technical models and processes (Lemmen et al., 2021).

In this paper, we compare the data model defined with the LADM standard with the attributes of physical utility networks, as well as interests on them. For this objective, we used the comparative method. By using Croatia as an example and comparing the LADM classes with the attributes of utility networks, we are looking for the similarities and differences between them, with the aim to conclude whether LADM can be implemented for the utility cadaster.

The comparative method in this paper is used in two steps:

1. Determining the attributes of infrastructure that are represented in the classes defined by the LADM standard.
2. Determining the attributes that are missing from LADM and researching whether they can be represented with external classes.

3. UTILITY REGISTRATION

Research about utility registration is done mostly under the topic of 3D cadasters. From the bibliometric analysis of research papers since the publication of LADM in 2012 to 2020, it can be observed that LADM had a significant impact on land administration in many jurisdictions around the world. Many of the studies were conducted on the topic of country profiles which showed interest for the implementation of LADM in land administration. Other studies showed interest for the implementation of LADM for various purposes of land administration, such as valuation, coastal management, land cadaster, marine cadaster, and utility registration (Polat et al., 2022).

Registering the physical features of utility networks is outside the scope of LADM, but since information about the physical features of utility networks is vital to some countries, either for creating a base map or other purposes, they often introduce necessary data to their country profiles. Such applications show that LADM is flexible and that it can be used effectively for linking cadastral information with other relevant information, such as utility network registers (Góźdź & van Oosterom, 2016).

Studies about the registration of utility networks based on LADM is not as widely researched as building or land parcel registration. Few that were conducted, such as the proposal for the subsurface utility network cadaster based on LADM from Brazil, confirmed the appropriateness of the LADM to model utility networks, while its flexibility allowed to create specific classes needed for full utility registration that are not part of the core LADM classes (Silva & Carneiro, 2020).

The approach in Serbia that regards physical infrastructure as separate legal objects that can be sold and leased gives another valuable insight in utility registration. Therefore, the Serbian country profile also contains utility network extension with classes needed for registering the physical features of utility networks (Radulović et al., 2019).

Different societies will have various approaches to solving certain challenges, and the same would go for the challenge of utility network registration. It can be observed in FIG's questionnaires on utility registration that approaches vary significantly, with some of the jurisdictions registering utilities as separate objects with unique cadastral numbers in land administration systems, while others registering only easements or tunnel spaces around utilities. Some jurisdictions have a centralized approach with high government regulations, while in others, utilities are registered with the municipality or even administered only by private companies. In conclusion, we can recognize two main approaches, one of which is national utility cadasters, such as those in the Republic of Croatia, which are usually established by regulations with the implementation coming years or decades later. The other approach involves companies managing most of the data with local jurisdictions coordinating the exchange of data through various systems or call centers (Dželalija & Roić, 2021).

In most jurisdictions, some of the main incentives for utility registration are safety and accident prevention, as well as other technical purposes. When it comes to the legal aspects of utilities, their impact on the rights on cadastral parcels that they cross is recognized, usually only in the form of easements. On the contrary, their own legal status and value is rarely recognized. As such, we can rarely see them being registered as property parcels, which means that it is not possible to register various legal interests on physical infrastructure, such as mortgages or leases.

The first discussions on utility registration in the Republic of Croatia started in the mid-20th century, with the first Rulebook on Methods and Mode of Operation in Surveying of Underground Installations and Objects was passed in 1969. Since then, numerous laws and rulebooks about utility registration have been passed with not much being implemented. The last law on State Survey and Real Estate Cadastre was passed in 2017, based on which State Geodetic Administration created the Rulebook on Utility Cadastre. The Rulebook proscribes the content, method of establishing, and management of the utility cadaster, and the manner of establishing a single infrastructure database and the information on the current or planned construction works, availability of infrastructure data and notices of current or planned construction works, manner of submission and type and structure of infrastructure data, infrastructure changes, and notices on current or planned construction works (Rulebook on Utility Cadastre, 2017).

The rulebook specifies the content of the utility cadaster. Therefore, the utility cadaster needs to have information on whether the utility infrastructure is underground, overhead, underwater, or overseas. It should have an information about the infrastructure purpose; data about technical characteristics; location; and data about owners, including name, address, PIN, and information necessary for communication, and whether the infrastructure is in use, abandoned, or removed.

Technical characteristics to be recorded about utility lines are voltage, type and number of cables for the electric grid, cable number for the electronic communication network, sewer dimensions, type of material, and number and profile of pipe for sewerage of the electric, electronic communication, and thermal infrastructure. For gas pipelines, information about the type of pressure, type of material, and pipe profile should be recorded. Data about the type of material and pipe profile should be recorded for water, gas, and drainage pipelines.
Data about type of material, pipe profile, and type of infrastructure should be recorded for protective pipes of all types of infrastructure, while for the associated facilities, data about type of facility should be recorded (Rulebook on Utility Cadastre, 2017).

4. LAND ADMINISTRATION DOMAIN MODEL AND LANDINFRA

LADM Edition I is a conceptual scheme focused on the land administration defined by the Technical Committee for Geographic Information of International Organization for Standardization (ISO) (ISO TC/211, 2012). LADM was defined with the aim of providing support for the development and improvement of land administration systems, as well as facilitating easy communication between different users with the use of a common data model.

The idea of LADM was first proposed in 2002 at the International Federation of Surveyors (FIG) congress in Washington. Thereafter, the first versions of LADM were presented to Open Geospatial Consortium (OGC), and later, at several more congresses sponsored by FIG. FIG submitted a proposal for adopting LADM to ISO as a new standard in 2008, and in 2012, LADM was accepted as an ISO standard (van Oosterom et al., 2013). The goals of LADM are establishing a common model-based ontology, support for software development for land use applications, streamlining data exchange between different land administration systems, and improving data quality (Lemmen et al., 2013).

LADM is organized in three packages and one subpackage (Figure 1). The packages relate to parties (package Party); administration, including rights, restrictions, and responsibilities (package Administrative); spatial data (package Spatial Unit); and subpackage for surveying and representation (subpackage Surveying and Spatial Representation) (ISO TC/211, 2012).

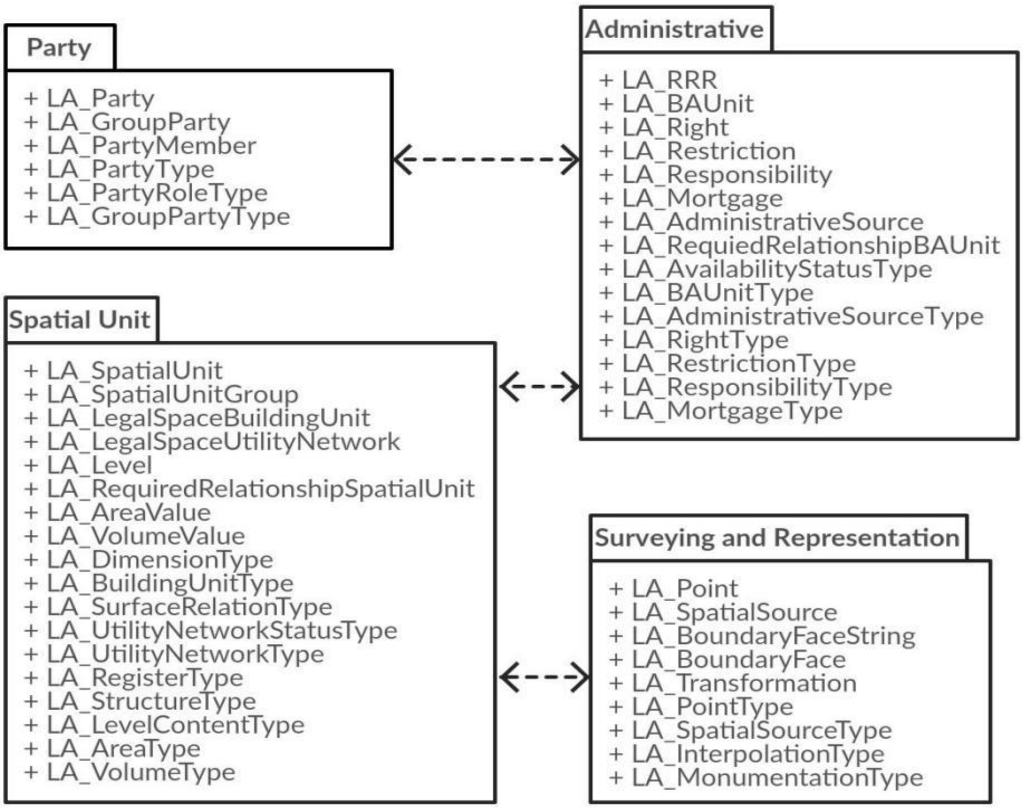

Figure 1. Three packages and one subpackage of LADM (ISO TC/211, 2012)

LADM can be implemented flexibly and can be extended and adopted to specific local needs. LADM is therefore divided into these four packages, so that they can be independently maintained, irrespective of the addition of any new packages (Lemmen et al., 2015).

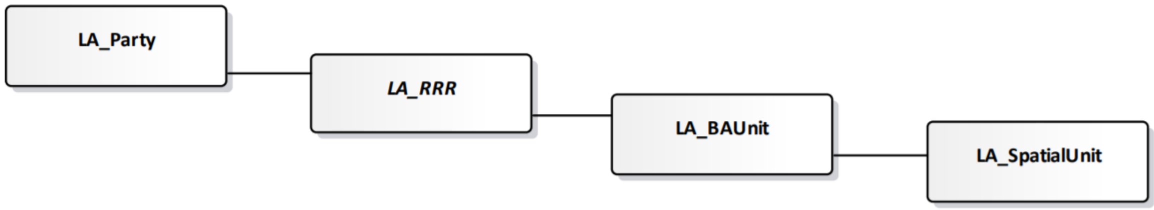

Figure 2. Basic classes of the core LADM (ISO TC/211, 2012)

LADM is based on four core classes (Figure 2):

- LA_Party – instance of this class represents parties;
- LA_RRR – its subclasses LA_Right, LA_Restriction, and LA_Responsibility represents rights, restrictions and responsibilities;
- LA_BAUnit – instance of this class represents basic administrative units; and
- LA_SpatialUnit – instance of this class represents spatial units.

The Party package contains classes that represent legal and natural parties that have interests in land units. Therefore, in the Party package, there are classes for representing a single party or a group of parties and their roles within the land administration.

The Administrative package contains classes that represent interests between parties and basic administrative units. LA_BAUnit describes the core characteristics of administrative units and is associated to LA_RRR class that, together with its subclasses (LA_Right, LA_Restriction and LA_Responsibility), covers rights, restrictions, and responsibilities.

The Spatial unit package with its subpackage for surveying and representation represents spatial units (e.g., cadaster parcels and legal space of utility networks) and their spatial/geometric representation.

LADM Edition II is currently under development and should enable more support for land management such as spatial planning or valuations. Moreover, it is proposed with technical models and processes, which will push LADM closer to implementation. The second edition of LADM will consist of six parts, with Part 1 Fundamentals having all the basic components that will be shared by all other parts of LADM Edition II. The second edition of LADM will be backward compatible with the current edition of LADM (Lemmen et al., 2021).

LADM is developed in such a way that it is flexible and easily extended for different land administration systems in jurisdictions through national profiles. Kalogianni et al. (2021) proposed the methodology and good practices for developing national profiles that work for both Edition I and Edition II of LADM. The development of national profiles consists of three phases, with the first phase being scope definition and analysis of the current situation in LAS. The second phase consists of mapping the current model to LADM classes, creation of

UML models, and populating code lists and conformity tests. Finally, the third phase is testing with real data collection, instance level diagram creation, database/XML implementation, and population and visualization.

When it comes to utilities, we have several types of spatial units: land parcels crossed by utilities, legal space of the utility network, and the physical space of the utilities. The physical space of the utilities would be for example the water pipeline or the pole of an electrical grid. The physical space of utilities is thus owned by the infrastructure owner, as is the case with a condominium. The legal space of the utility network contains the extra space around the infrastructure itself, for example, the safety zone around the pipeline or easement on the land parcel that the infrastructure is crossing. Therefore, the legal space is usually not owned by the same physical or legal person as the infrastructure itself but is a form of restriction on the rights on the land parcel.

The legal space of utility networks is therefore not necessarily the same as the physical space of utilities; instead, it often contains the safety zone around the pipelines and various restrictions to other land rights for the purpose of access to the utilities (Lemmen, 2014). Therefore, as LADM is concerned only with the legal space of utility networks and the legal space contains the physical space of utility networks, only LA_LegalSpaceUtilityNetwork is included in the standard (Lemmen et al., 2019).

The legal spaces of utilities are described with the class LA_LegalSpaceUtilityNetwork. Additionally, an important class for describing the interests and the connections between parcels and the legal space of utility networks is LA_Level.
LA_Level describes the set of spatial units with coherent geometries, topologies, or thematics. LA_Level can then be used to represent different registers, such as a utility and land cadaster. Connections between different levels are achieved with topological operations (Figure 3), and in cases, where geometries are not adequate, the class LA_RequiredRelationshipSpatialUnit can be used (Lemmen, 2014).

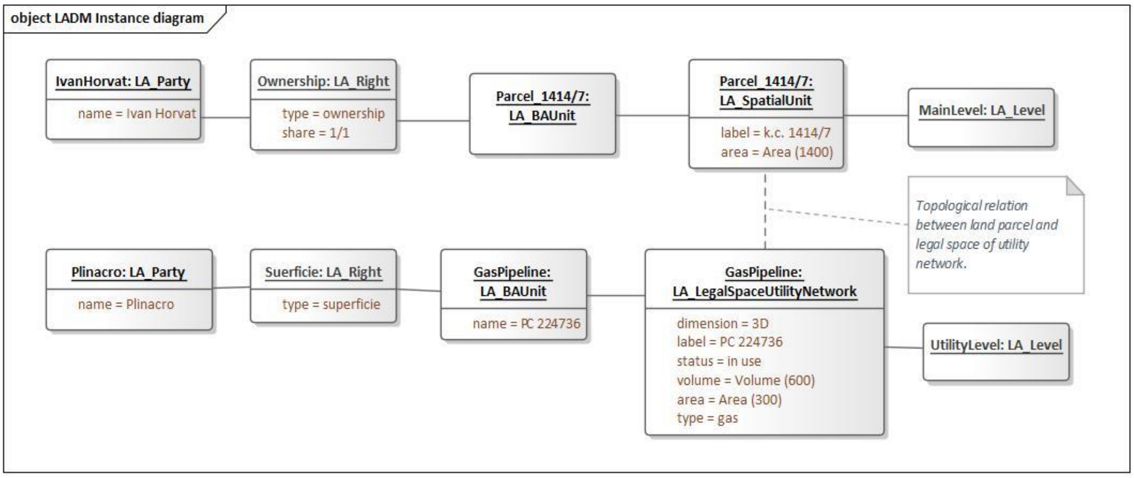

Figure 3. Connections between land parcel space and legal space of utility network

LandInfra is an OGC standard that addresses a subset of LADM, and its scope is focused on modeling civil engineering infrastructure facilities and projects, such as roads, railways, and wet infrastructure, while minimizing the legal aspects of land administration (Scarponcini et al., 2016). LandInfra has special classes for representing easement, land parcel, superficie objects, and physical space of utility (Figure 4). An easement is represented with the Easement class, with its geometry represented by SpatialUnit. A land parcel is represented with the LandParcel class and its geometry with SpatialUnit. The Superficie object and its geometry is represented with the SuperficieObject class. Finally, a part of the physical utility is described with the FacilityPart class.

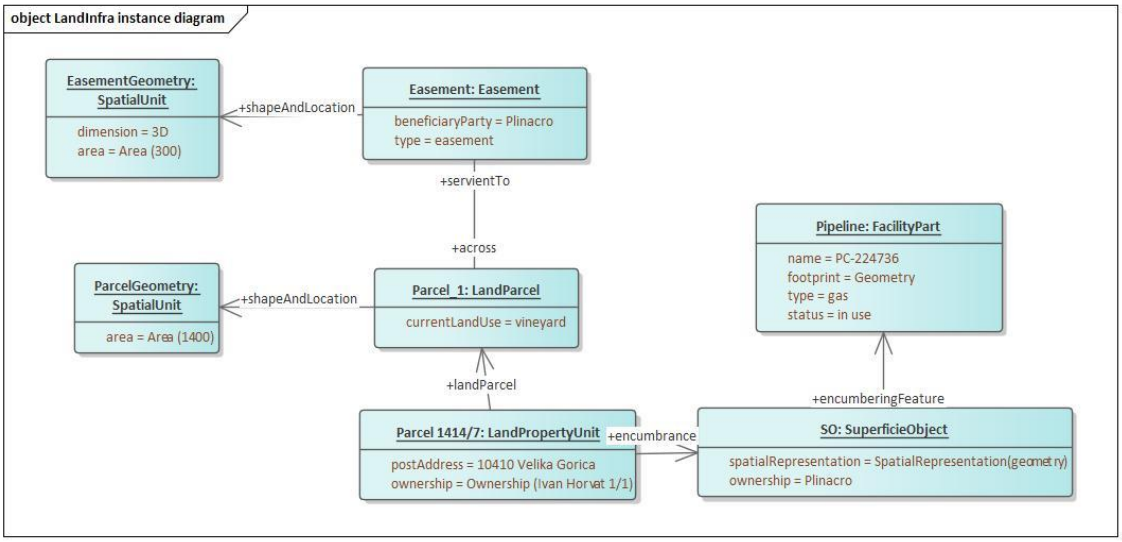

Figure 4. Instances of land parcel, easement, superficie, and physical space of utilities

When comparing classes between LADM and LandInfra, we recognize that LADM has a more generic approach, while LandInfra is focused on the specific scope of land and infrastructure interaction. In LADM, we have the LA_BAUnit class that represents an entity that is the subject of registration in land administration systems and has associations to the land parcel and party via rights, restrictions, and responsibilities. An equivalent class in LandInfra is LandPropertyUnit, which specifies ownership to a part of the surface of Earth. LandPropertyUnit has association through attributes for the land parcel and ownership, which then specifies the party. For describing spatial units and land parcels in LADM, there is the class LA_SpatialUnit, with its additional alias LA_Parcel. LA_SpatialUnit has attributes for describing the shape, location, and bounding elements of spatial units. For the same purpose in LandInfra, there are classes LandParcel and SpatialUnit. The LandParcel class has the basic information about the land parcel and a reference to a single SpatialUnit object, which is a continuous geometrical entity and describes the shape, location, and bounding elements of the land parcel. Class Easement from LandInfra describes easements, or the right to certain use within the space across one or more instances of a servient land parcel. LADM has a more generic approach with the class LA_Restriction that is used to describe easements on land parcels, and for all other restrictions in LA, such as mortgage.

5. TOWARD IMPLEMENTATION CONCEPT FOR UTILITY INFRASTRUCTURE BASED ON LADM

When it comes to the public utility infrastructure, in the scope of LADM are relationships between parties and interests on the infrastructure, while the physical representation of the infrastructure is left to the external classes through the attribute extPhysicalUtilityNetworkID of the LA_LegalSpaceUtilityNetwork class. The division is made because the space of interest does not necessarily overlap with the physical space of some infrastructure (Lemmen et al., 2015). In order for LADM to meet the needs of the administration of the public utility infrastructure, it is necessary to extend it with classes that will represent the physical features of the utility infrastructure (Dželalija & Roić, 2018).

This section describes the proposed LADM-based data model for representing the physical features of the utility infrastructure. As mentioned earlier, LADM is concerned with the legal space of utility networks; therefore, in LADM, there is a class LA_LegalSpaceUtilityNetwork for representing utilities' legal space and additionally a reference to an external class ExtPhysicalUtilityNetwork for representing the physical aspects and characteristics of utility networks. The proposed data model is developed on top of the external class ExtPhysicalUtilityNetwork with the aim to describe the physical characteristics of the utility infrastructure in more detail. The model is designed on the basis of the experiences and needs of the utility cadaster in the Republic of Croatia.

This model includes classes that represent the physical infrastructure of electric, electronic communication, oil, water supply, heat, gas, and sewerage networks. Among the infrastructure of these utility network types, the data model recognizes three types of infrastructure objects: pipelines such as water, gas, or oil pipelines; cables, such as high voltage electric cables; and other associated utility objects, such as heating plants.

In this model, shown in Figure 5, the physical features of the utility infrastructure are represented by the UM_PhysicalUtilityNetwork class. Every physical infrastructure has its manager and owner, which are often the same legal person. The owner and his right of ownership of the physical infrastructure is represented through the existing LADM classes, mainly LA_Party and LA_Right as well as their respective class relationship. Manager is represented through the specialization of the LA_Responsibility class, UM_Manager. As the infrastructure registers require managers to have information needed for communication, the UM_Manager class, in addition to the reference to the LA_Party class, has attributes for phone and email. The UM_PhysicalUtilityNetwork class has several more attributes needed to describe its properties: status, inherited from LA_LegalSpaceUtilityNetwork, with reference to the code list LA_UtilityNetworkStatusType. Status shows whether the infrastructure is in use, abandoned, or planned. DateOfConstruction records the date of construction of the infrastructure. NetworkType is in reference to the code list LA_UtilityNetworkType. Network type is used to recognize the network physical infrastructure to which the infrastructure belongs, e.g., water or drainage, and surfaceRelation is inherited from LA_SpatialUnit, with reference to the code list UM_SurfaceRelation, which shows the relative position of infrastructure in relation to the surface, i.e., underground, underwater, etc.

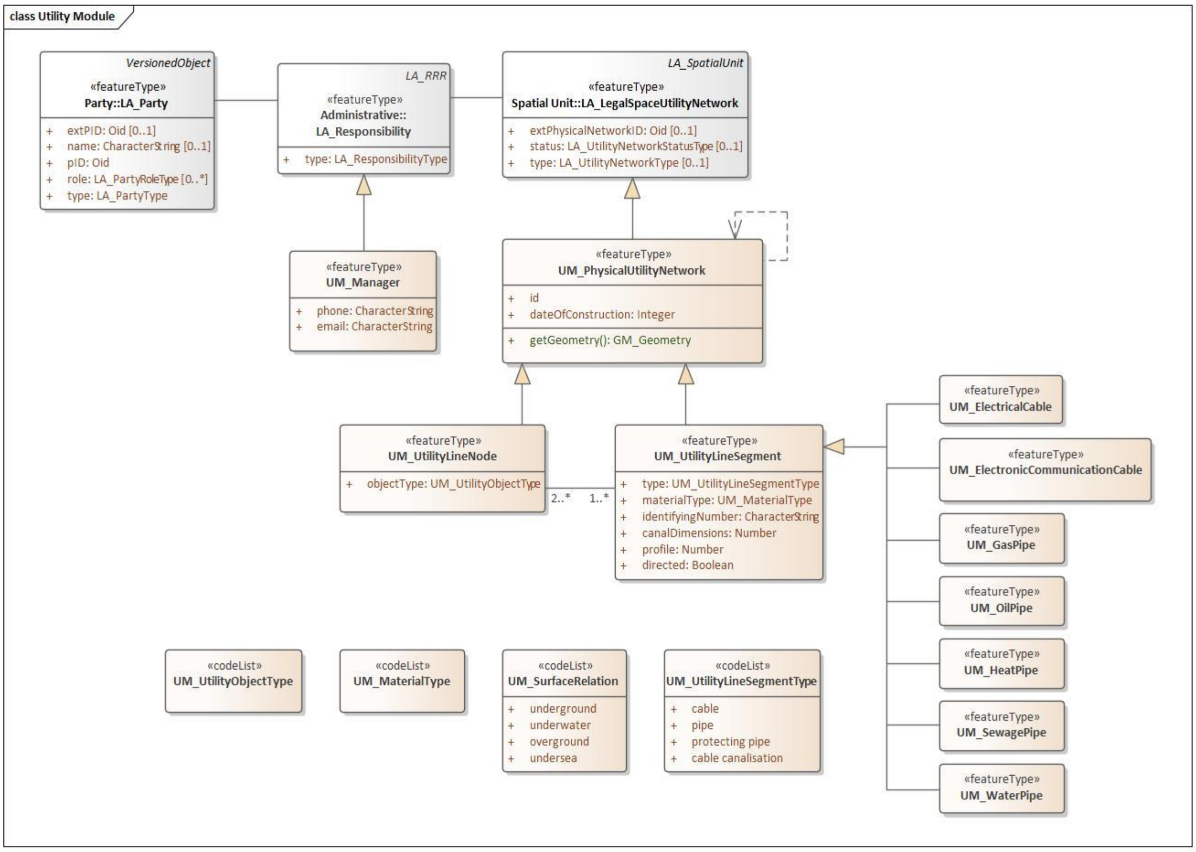

Figure 5. Utility implementation concept model

Physical Infrastructure consists of two topological types of objects: node and line objects. Node objects, or infrastructure objects, are the starting and ending points of the infrastructure (i.e., power plant and electricity house connectors) as well as incidental intersections and nodes (i.e., poles, manholes, etc.). Infrastructure lines are linear objects, or pipelines and cables. Therefore, UM_PhysicalUtilityNetwork has two more specializations UM_UtilityLineNode and UM_UtilityLineSegment. For representing node objects, the UM_UtilityLineNode subclass is used. The UM_UtilityLineNode class has a single additional attribute, objectType, with reference to the code list UM_UtilityObjectType. The UM_UtilityLineSegment subclass is used to represent the linear infrastructure and has several additional attributes: type, with reference to the code list UM_UtilityLineSegmentType. Type shows whether a certain line is a pipe, cable, protecting pipe, or cable canalization. MaterialType, with reference to the code list UM_MaterialType, records information about the building material of the infrastructure.

IdentifyingNumber is the unique identifier of a utility line segment. CanalDimensions os an optional attribute about the dimensions of the canal, if the type of infrastructure is cable canalization. Profile is an optional attribute about the pipe profile, if the type of infrastructure is pipe. The parameter named directed shows whether the infrastructure has a flow direction. UM_UtilityLineSegment is furthermore divided into abstract subclasses for each specific infrastructure.

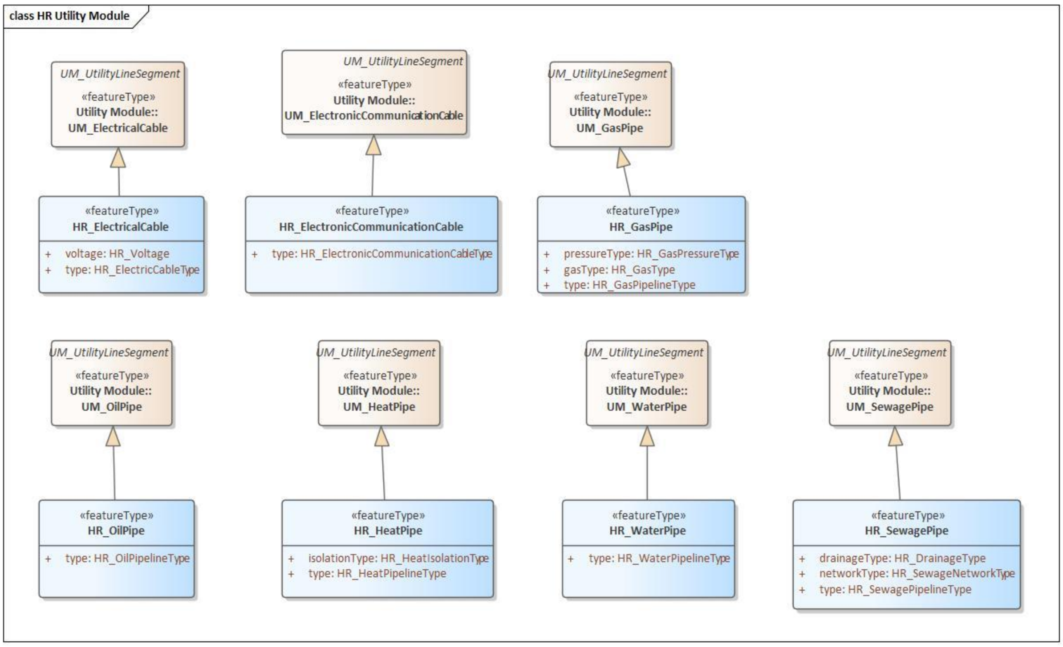

Figure 6. Croatian country profile for utility extension model

Additionally, the implementation of abstract classes for specific infrastructures is given through the Croatian country profile (Figure 6): HR_ElectricalCable is used for representing electrical cables and has two additional attributes: voltage and type of cable.

HR_ElectronicCommunicationCable is used to represent communication cables, such as TV and internet cables. HR_GasPipe is used to represent gas pipelines and has attributes for gas pressure, gas type, and type of pipeline. HR_OilPipe is used to represent oil pipelines and has an attribute for the type of pipeline. HR_HeatPipe is used to represent pipelines of heating networks and has attributes for pipe isolation type and type of pipeline. HR_WaterPipe is used to represent water pipelines and has an attribute for the type of pipeline. HR_SewagePipe is used to represent pipelines of sewage networks and has attributes for drainage type, sewage network type, and type of pipeline.

The example discussed in the previous section can now be taken and designed using the LADM implementation concept for a utility network. The right of superficies and ownerships of legal and physical space of a utility can be shown by the existing LADM classes, as well as the parcel that the utility is intersecting. As shown below in Figure 7, the gas company (Plinacro:LA_Party) has a superficie (Superficie:LA_Right) for its gas pipeline. Through a topological operation, the relation between the superficie geometry, which is on the utility level (UtilityLevel:LA_Level), and the geometry of the land parcel (Parcel_1414/7:LA_SpatialUnit), which is on the main level of land cadaster, can be shown. The physical infrastructure of the shown gas pipeline can be modelled with the proposed implementation concept. The physical gas pipe is shown on a separate utility cadaster level (UtilityCadastreLevel:LA_Level) with the UM_GasPipe class with its technical attributes and physical geometry, while the geometric relation between the land parcel and the physical gas pipe can be shown using topological operations between two levels. In Croatia, the rights, restrictions, and responsibilities are registered in the land registry, while the geometry and features of spatial units are registered in the cadaster. Utility networks and their managers are registered in the national utility cadaster.

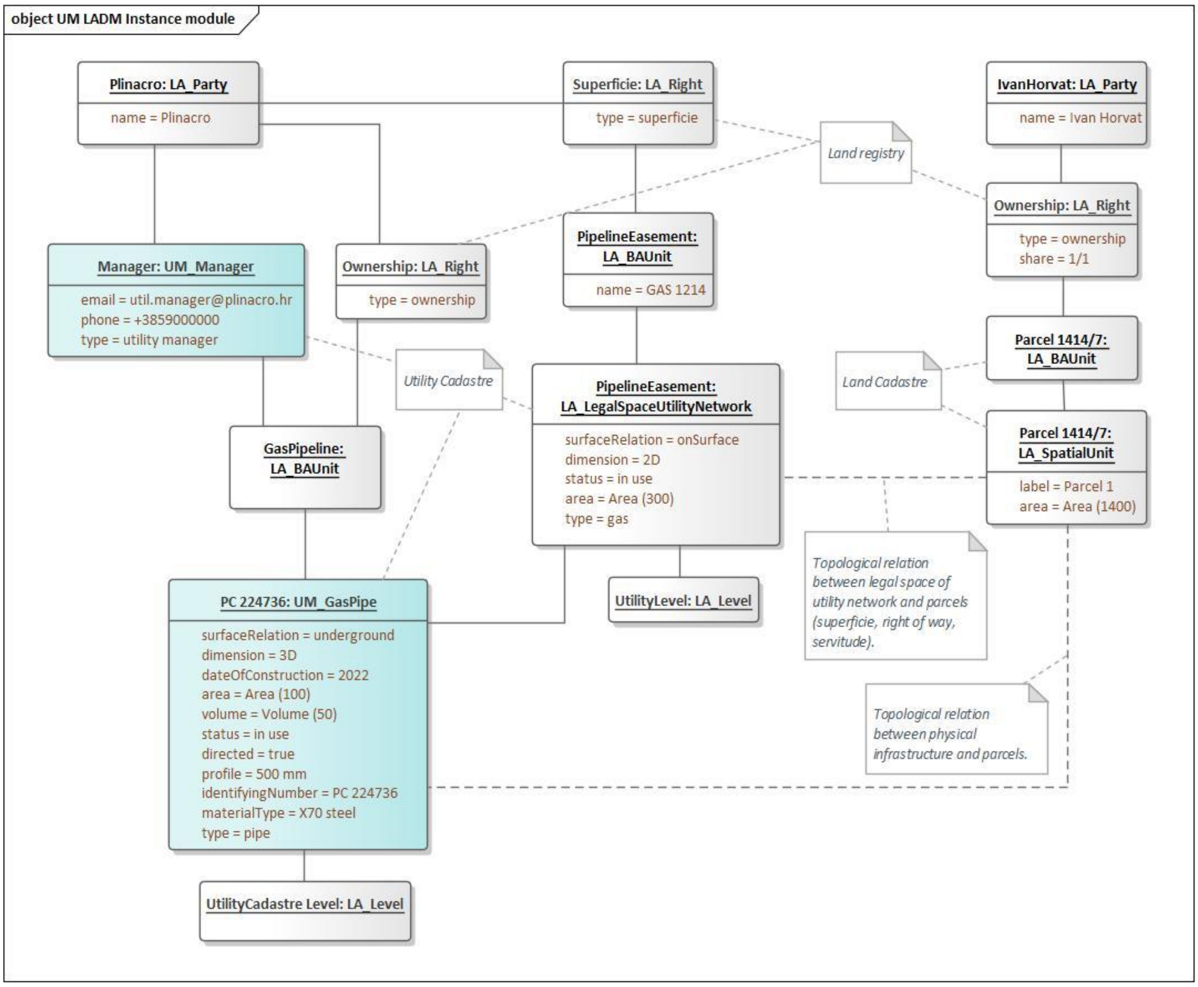

Figure 7. Implementation with utility model

As mentioned in the previous sections, LADM Edition I is concerned with the legal spaces of utility networks that affect the rights on other spatial units registered in the land administration, i.e., easements and the right of servitude on land parcels. Information about the physical features of utility networks is therefore left to external classes and registers. In contrast, the LandInfra standard is focused mainly on the technical purposes for land and civil engineering infrastructure facility as well as their relationship with land parcels.

In addition to recognizing the influence of utility networks on the rights on spatial units registered in the land administration, many jurisdictions consider utility networks as separate legal objects that can be owned, sold, or mortgaged for instance, as in the case of other real estate, such as buildings. Physical utility networks therefore have associated rights, restrictions, and responsibilities that model their own relationship with parties, i.e., mortgages, ownerships, etc. The proposed implementation concept of LADM for utility networks would enable one to register physical utility networks in a uniform manner as other related spatial units in the land administration system.

6. CONCLUSION

Besides various facilities, the utility infrastructure consists mainly of lines for distributing or transmitting electricity, water, oil, gas, and other resources or commodities essential to modern society. As such, utility lines span across large areas and, in process, traverse many land parcels. These lines usually pass land parcels under or over ground, which often leaves land use and parcel ownership intact, but introduces certain restrictions on the existing parcel ownership rights and adds additional rights for utility owners. Since LADM is already concerned with rights, restrictions, and responsibilities on land parcels, the best practice would be to introduce the utility infrastructure level into LADM through the implementation concept.

The LADM implementation model for utility infrastructure proposed in this paper was developed mainly with reference to the national utility cadaster and needs of the Republic of Croatia but can be implemented for others considering the introduction of specific country profiles. The concept of the implementation of a utility infrastructure extension model based on LADM would enable closer integration and standardized exchange of data between the utility cadaster and its data with the land cadaster and other related registers, such as the register of buildings.

As mentioned before, many jurisdictions consider utility networks as separate legal objects that, in addition to their relationships with other spatial units registered in LA, have their own RRRs and relationships with parties, i.e., physical or legal persons. Therefore, it would be beneficial to have them modelled with LADM as well. The concept of the implementation would enable better support for utility registration and implementation and could contribute to the development of a new edition of LADM.

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