Towards 3D Utility Network Cadastre: Extended Serbian LADM Country Profile

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Key words: utility network cadastre, LADM country profile, 3D cadastre, LIDAR, GPR

SUMMARY

Survey, establishment and maintenance of utility network in Serbia are defined by the Law on state survey and cadastre (2009), the Rulebook on survey and utility network cadastre (2010), the Manual for implementation and maintenance of the utility network digital database (2005) and the Law on the procedure for registration in the real estate cadastre and utility network cadastre (2018). The utility network cadastre is the main register of the utility lines and rights to them, together with the property owner's rights, and contains information on the following: water supply network, sewage and drainage network, hot water network, electricity network, telecommunications network, pipeline network, gas pipeline network, and common facilities. The Law on state survey and cadastre states the necessity for implementing a unified information system of both the real estate cadastre and the utility network cadastre, but this has not yet been achieved.

Unified data model is presented in proposed LADM country profile for Serbia (Radulović et al, 2017). However, by analyzing the appropriate legislation, for the case of Serbia it is necessary to extend the class set for utility network cadastre. For each phenomenon in one utility network, a type of preferred geometrical representation is specified. This means it is necessary to extend Serbian LADM country profile to fully represent unified data model as Law requires.

Another issue is related to maintenance of utility network data. In practice, when there is change done on lines by the right holders it is necessary to implement the change in the utility network cadastre. In many situations it is not done and the actual state does not correspond to the one in the utility network cadastre. In these situations it is necessary to find a way how to get correct data without digging on the field in the case of underground utilities. As a solution for underground utilities a Ground Penetrating Radar (GPR) can be used (Ristić et al., 2017 and LIDAR technology for powerlines (Popović et al., 2017). This data can be used as an input for the utility network cadastre. In this paper, we analyze how to link 3D data to the data model, and also analyze the use of metadata to support the access and usage of 3D data for the legal purposes.

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1. INTRODUCTION

The utility network cadastre is the main register of the utility lines and rights to them, together with the property owner's rights, and contains information on the water supply network, sewage and drainage network, hot water network, electricity network, telecommunications network, pipeline network, gas pipeline network, and common facilities. According to the Law on state survey and cadastre a unified information system of both the real estate cadastre and the utility network cadastre should be developed, but this has not yet been achieved. There is a need to integrate existing subsystems into one unifying data model that will be completely based on current legislation and standards in the field of spatial data and land administration. According to the current legislation, a single utility line together with the belonging connectors, devices or facilities is a subject of rights registration in the utility network cadastre, so in the sense of LADM, a utility line can be considered as spatial unit a represented by the class derived from the LADM class LA_LegalSpaceUtilityNetwork. The utility network cadastre requires information on cadastral parcels on which the utility line is located. If the right holders of the utility lines are not at the same time the right holders of the parcels on which the utility lines are located, they must ask for the permission from the right holders of the parcels to build or maintain utility lines. Therefore, a link between a utility line and parcels must be established and maintained. In order to solve these issues, we propose extended Serbian LADM country profile to introduce unifying data model of real estate cadastre and utility network cadastre.

Another issue that may be raised is the use of 3D data in the context of the utility network cadastre. The integration of subsurface utility networks in 3D cadastre has already analyzed by Pouliot and Girard (2016). Traditionally, the utility network cadastre uses 2D data for spatial representations of the data on utility lines. However, current technology trends enable increasing use of 3D data. There are several research project undertaken on the utility network for the purpose of the utility network cadastre including usage of Ground Penetrating Radar for surveying optical and other sub-surface networks (Ristić et al., 2017) and usage of LIDAR for surveying electric power utility network (Popović et al., 2017). 2D data about utility lines have been derived from 3D data obtained in the project in order to fit in the prevailing 2D paradigm. However, this raised the question on how this 3D data can be preserved and used in utility network cadastre. The solution we propose is based on linking the spatial units with its 3D spatial source and usage of metadata that describes all the relevant aspect of the data, until the solutions for the more tight integration are found.

The paper is structured as follows. After the introduction, Section 2 provides an overview on how the utility network cadastre in Serbia is organized based on the national legislation. This Section also emphasizes the issues that arise during the implementation of the national legislation and necessity to introduce unifying data model of real estate cadastre and utility network cadastre through the development of the extended Serbian LADM country profile. Section 3 describes examples of using 3D data for utility network cadastre and Section 4 presents means for facilitating this data through usage of metadata. Conclusions and future work is given afterwards.

2. UTILITY NETWORK CADASTRE IN SERBIA

Survey, establishment and maintenance of utility network in Serbia are defined by the Law on state survey and cadastre from 2009 ("the Law"), the Rulebook on survey and utility network cadastre from 2010, the Manual for implementation and maintenance of the utility network digital database from 2005 ("the Manual") and the Law on the procedure for registration in the real estate cadastre and utility network cadastre from 2018 ("the new Law"). The utility network cadastre is the main register of the utility lines and rights to them, together with the property owner's rights, and contains information on the following: water supply network, sewage and drainage network, hot water network, electricity network, telecommunications network, pipeline network, gas pipeline network, and common facilities. The devices and plants that are built on the utility lines, which enable the functioning and proper use of the lines and are fully incorporated parts of the lines, also belongs to the utility network cadastre. The survey of the utility lines is financed by the right holders on the lines, local government or other interested legal and natural persons. The data collected during the survey is used for establishing a utility network cadastre. The utility network cadastre consists of spatial source documents, administrative source documents and utility network database. Spatial source documents are a set of the documents and data generated in the process of designing and realization of the surveying of the lines and documentation on the lines that are available by state authorities, companies and other organizations. Administrative source documents are a set of documents on the basis of which the entry or deletion of entries on the lines has been made.

For each type of utility network a set of necessary attributes that are collected during the measurements of lines are defined: for water supply network a zone number, material type and pipe diameter should be measured; for electricity network a voltage and number of cables of the same voltage should be measured, etc. The attributes and classes for each utility network type are defined in the Manual.

The new Law regulates the rules of a registration procedure in the real estate cadastre and the utility network cadastre, their maintenance, the subject and types of entries in that procedure and rules of procedure for issuing documents from the mentioned registers. This new Law extends the Law form 2009 in this area. Novelties are related to the use of e-Counter service for submitting requests to improve the performance of cadastral services to users. It is anticipated that each property and utility line will be assigned a unique property identification number.

In the process of utility lines survey, data on property rights, right of use and other real rights prescribed by the laws, data on holders of these rights are collected. One or more investors, who have the right of ownership or joint ownership on the cadastral parcels on which the utility line is located, are entered as right holders on the utility line. Apart from the registration of the owner of the property right, other real rights - mortgages, easements and notices can be entered on the utility lines.

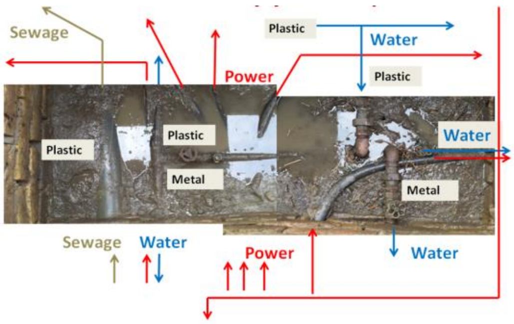
Maintenance of the utility network cadastre includes the implementation of the changes prescribed by the laws in the utility network cadastre database. The procedure for maintaining is initiated at the request of the right holder who submit the administrative and spatial documents that are the basis for the change of data.

The documents that can be issued from the utilitiy network cadastre are cadastral plan for lines and utility line folio. Cadastral plan for lines is a two-dimensional representation of the lines at the national projection level contatinig data on lines and related facilities and devices, characteristic attributes, related cadastral parcels, etc. Utility line folio is the basic document on the lines and real rights on them. It contains data on cadastral number of line, the name of the city or municipality, the type of the line, the name of the line (from the project documentation), basic characteristic data on the line, the length of the line, the name and address of the owner or holder of the line, type and scope of the right and data on restrictions on the line. An integral part of the utility line folio is an annex containing data on the cadastral parcels on which the line is located. Utility line folio is a concept by which the data in utility network cadastre are organized.

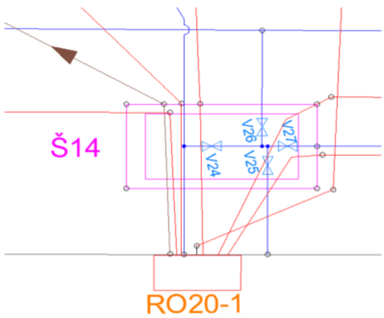
Article 157 of the Law states the necessity for implementing a unified information system of both the real estate cadastre and the utility network cadastre, but this has not yet been achieved. A need exists to improve the current cadastral system and to integrate existing subsystems (one is utility network subsystem) into one unifying data model that will be completely based on current legislation and standards in the field of spatial data and land administration.

There are several problems in existing utility network cadastre that are not yet resolved. A number of municipalities in Serbia do not have an established utility network cadastre at all. For those that have established utility network cadastre data is usually not up-to-date. In the past it was not unusual that utility lines were dug in without registering in the register. Today, a legally defined procedure for registering utility lines is followed, but the process of registering changes in the registry is time-consuming. The poor synchronization in conducting the works on utility lines, between the different companies that are responsible for lines and local government responsible for spatial planning, results in frequent digging, ground subsidence and damaging the utility lines. Due to ground subsidence, damage and displacement of the lines, there is a lack of harmonization of data in the register and on the field. Data on rights and restrictions are stored separately from geometries and attributes of the utility lines which makes it difficult to issue correct data to the parties.

Data for utility network cadastre are 2D data stored in shp and dxf files. Another issue is related to the situations where the 2D view does not give a good insight into the position of the utility lines, like crossing or passing of the lines at a sharp angle, crossing of the utility line from the subterranean to the above ground and vertical installation of utility lines in the same trench, due to the lack of space in the zone between the road and the buildings. In older factories, parts of utility line installations pass under the buildings. Also it is often in factory shafts that there are many pipelines and cables that overlap one over the other due to upgrading of the system and due to other needs. Figure 1 (a) shows the photo of one shaft in factory with the indicated type of the utility line. Figure 1 (b) shows a 2D map of this shaft in utility network cadastre. It is very complicated, so in this and other mentioned situations an overview in 3D could help user to understand the position of the lines on the terrain.



(a)



(b)

Figure 1. Photo of a shaft in a factory (a); 2D map of a shaft in utility network cadastre

3. EXTENDED SERBIAN LADM COUNTRY PROFILE

Unified data model, that combines real estate and utility network cadastre, is presented in proposed LADM country profile for Serbia (Radulović et al, 2017).

Basic classes of Serbian LADM profile for unified data model are shown on Figure 2. The RS_SpatialUnit class describes spatial objects in the cadastre, including parcels, buildings, and parts of buildings, as well as utility networks, which are part of the utility network cadastre. The country profile allows the joining of the real estate and utility network cadastre data as required by the Law by introducing the RS_LegalSpaceUtilityNetwork class. The types of utility networks are defined within the RS_UtilityNetworkType code list. Additional association is added between RS_Parcel and RS_LegalSpaceUtilityNetwork since there is need to have the information about parcels on which one utility line is located.

The Law describes the legal aspects on utility lines on the same way like for real estate cadastre. This means that profile classes RS_Party and RS_RRR with its subclasses for rights and restrictions that are mortgages, easements and notices, remains the same for utility line cadastre (Radulović et al, 2017).

Class RS_BAUnit for real estate cadastre represent the main concept of keeping data in Serbian cadastre, that is real estate folio for parcels, buildings and part of buildings. Types of real eastate folios are defined within the RS_BAUnit code list. For this code list to be compliant with utility network cadastre it is necessary to extend it with value for utility line folio.

Cadastral plan for lines is a two-dimensional representation of the lines which means that the spatial profile for Serbia is 2D topological, so the RS_BoundaryFaceString class with GM_MultiCurve type was used for geometries.

Class RS_SpatialSource represent any source of 2D or 3D spatial data obtained with one of the methods like gnss survey, photogrammetry, laser scanning, ground penetrating radar, etc.

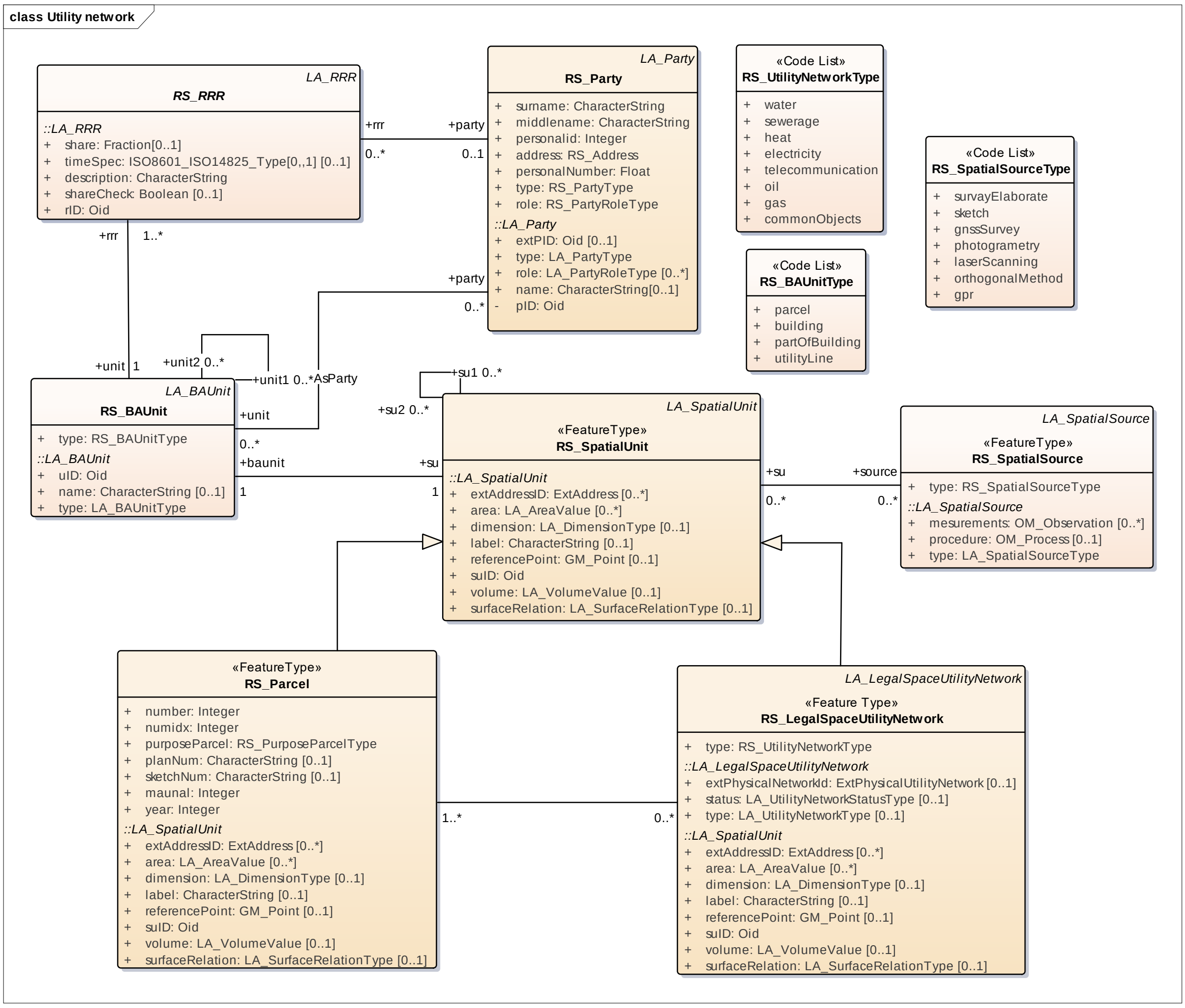


Figure 2. Basic classes of Serbian LADM profile for utility network cadastre

However, by analyzing the appropriate legislation, for the case of Serbia it is necessary to extend the class set for utility network cadastre. The objects of the digital database of the utility network cadastre are grouped by the type of geometrical representation: point, polyline and polygon. All phenomena that do not have the length or surface are represented with points. All phenomena that have a length, but not a surface are represented with polyline and all phenomena that have the surface are represented with polygons. For each type of utility cadastre, a necessary class set is defined. For each phenomenon in one utility network, a type of preferred geometrical representation is specified. This means it is necessary to extend Serbian LADM country profile to fully represent unified data model as Law requires.

Such data organization is the result of the use of shp files that have the ability to store only one type of geometry. When looking at any type of utility line cadastre, it can be concluded that its elements can be viewed as a network made up of nodes, link sets, and objects. Serbian network model for the use in utility network cadastre is shown on Figure 3. Three classes are defined RS_Node, RS_LinkSet and RS_Objects. These classes contain common attributes for the specific network element type.

Class RS_Node represents all connecting points in utility lines system like intersections, poles, shafts, etc. One node is described with elevation of the terrain and of the line to which is connected, with sketch, method used for data acquisition, scale… Class RS_LinkSet represents all links and sets of links between nodes, like utility lines and connectors. One link set represent one utility line which is described with position, source type, scale, number of lines, built material… Class RS_Objects represents facilities that are made along the lines and have a significant role in the functioning of the specific utility line system, like cable cabin, switchboard, extensions, etc. Object is described with elevation, method used for data acquisition, scale, source… Further generalization of elements in network model can be done by introducing INSPIRE Generic Network Model in utility network cadastre, but this is out of scope of this paper.

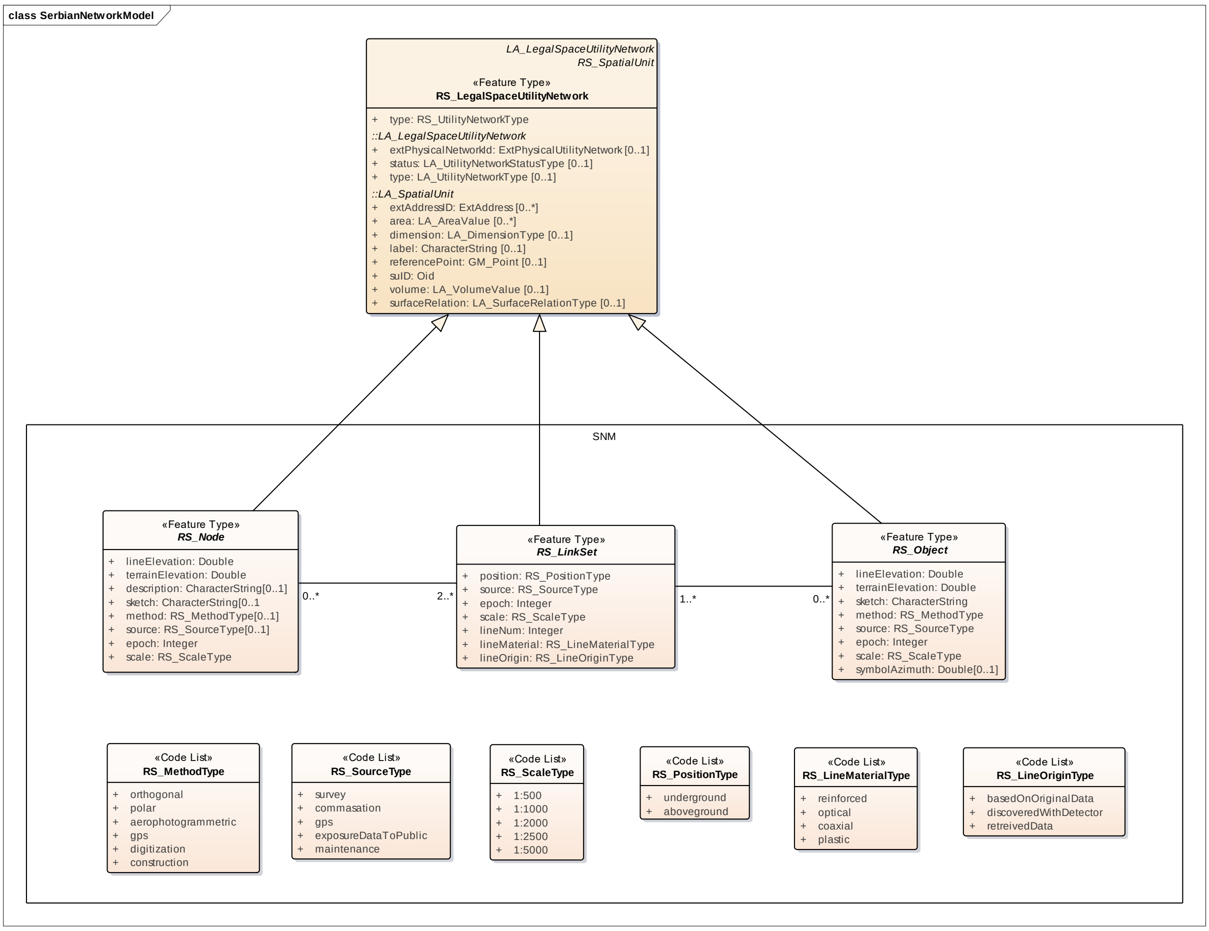


Figure 3. Serbian network model for utility network cadastre

This network model is base for each type of utility network. For example, to create classes for telecommunication network system it is necessary to specialize abstract classes RS_Node, RS_LinkSet and RS_Object. Telecommunication network is a system which allows remote transmission of information, so the resulting classes should represent specific elements of telecommunication network. In the case of RS_Node class, specialized classes are RS_Shaft, RS_IntersectionPoint and RS_Pole (Figure 4). RS_Shaft represent shafts that can have circle or square cover, and are described by shaft number and cover and bottom elevation. Intersection point is described by type, whether it is horizontal, vertical, branching or detailed intersection point. RS_Pole describes poles which can be made of wood, concrete, iron…. Such specialization should be also done for classes RS_LinkSet and RS_Objects. For other types of utility network (pipeline, electricity, gas pipeline…) the same procedure for creation class diagrams is predicted.

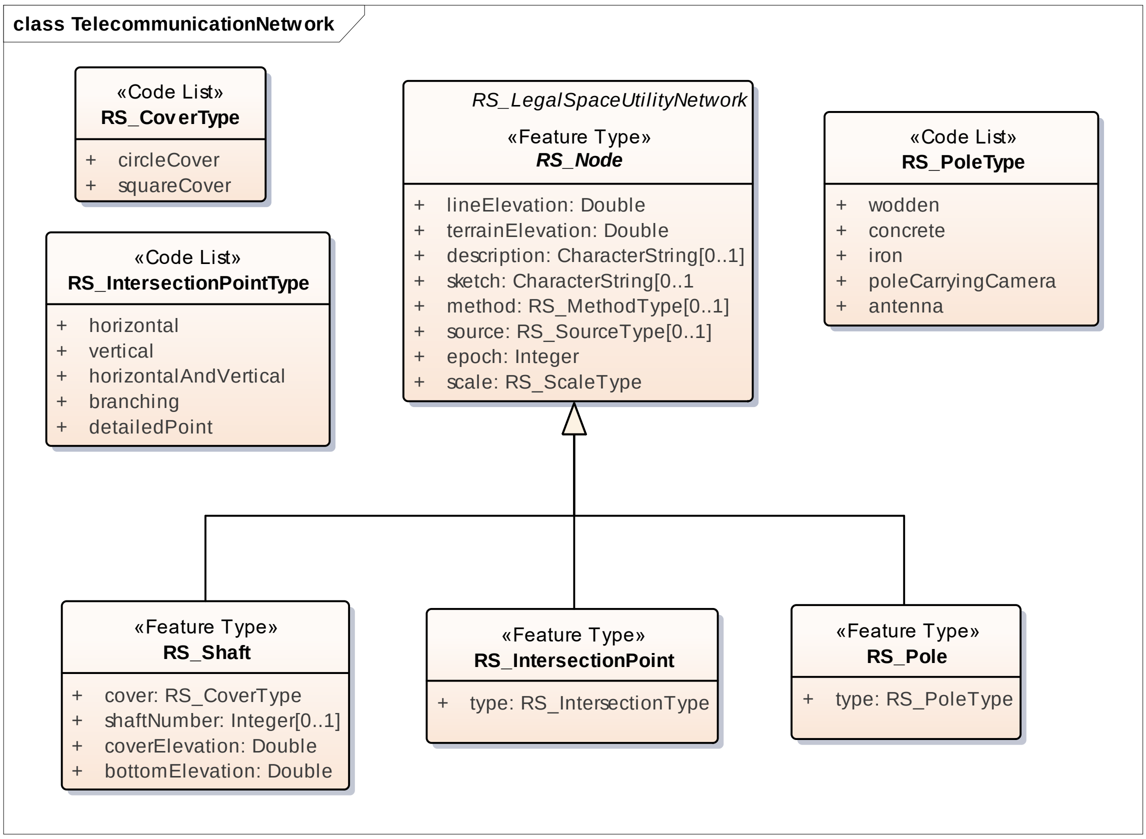
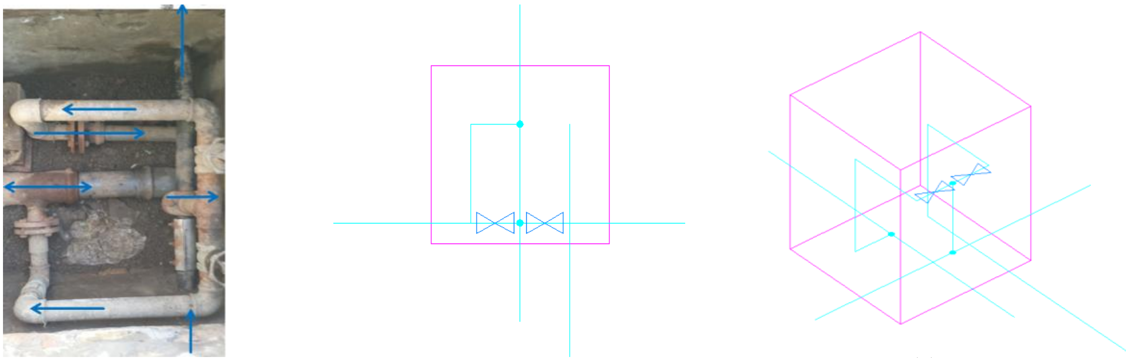


Figure 4. Specialization of class RS_Node for telecommunication network

4. 3D DATA FOR UTILITY NETWORK CADASTRE

Existing problems regarding maintenance and visualization in utility network cadastre are already mentioned in Section 2. In practice, when there is change done on lines by the right holders it is necessary to implement the change in the utility network cadastre. In many situations it is not done and the actual state does not correspond to the one in the utility network cadastre. In these situations it is necessary to find a way how to get correct data without digging on the field in the case of underground utilities. As a solution for underground utilities a Ground Penetrating Radar (GPR) combined with electromagnetic locator can be used (Ristić et al., 2017). Based on georeferenced radargrams, photographing and relative measurements, this technology allows user to transform results from the field in 2D or 3D models of underground utilities. This is particularly important since in the underground utility network there are a lot of examples of overlapping rights in 3D.

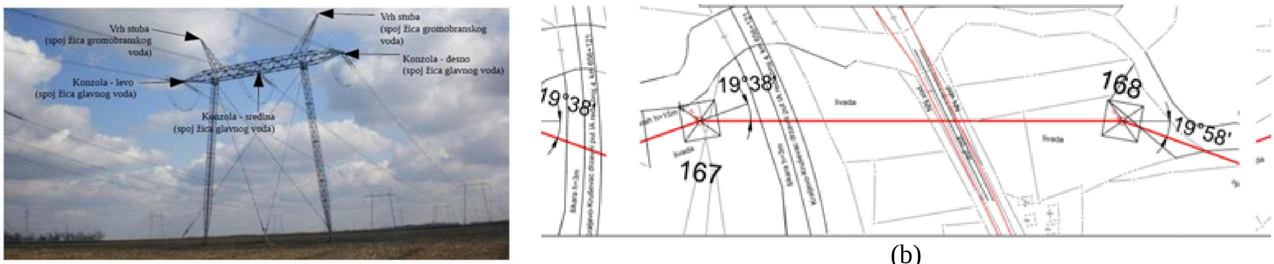
Figure 5 (a) shows the photograph of water pipes in the factory shaft. There are a lot of inputs and outputs from the shaft and branching where the pipes change direction to higher or lower levels. The arrows indicate the flow direction of the fluid through the pipelines. Figure 5 (b) shows a classic 2D view of the shaft where it is completely unclear how the pipeline in the shaft is organized. Figure 5 (c) represents the 3D view of the shaft and gives a clear picture of the position of the pipelines and devices in the shaft. The 3D model format is dxf, and 2D data can be converted to shp file.



(a) (b) (c)

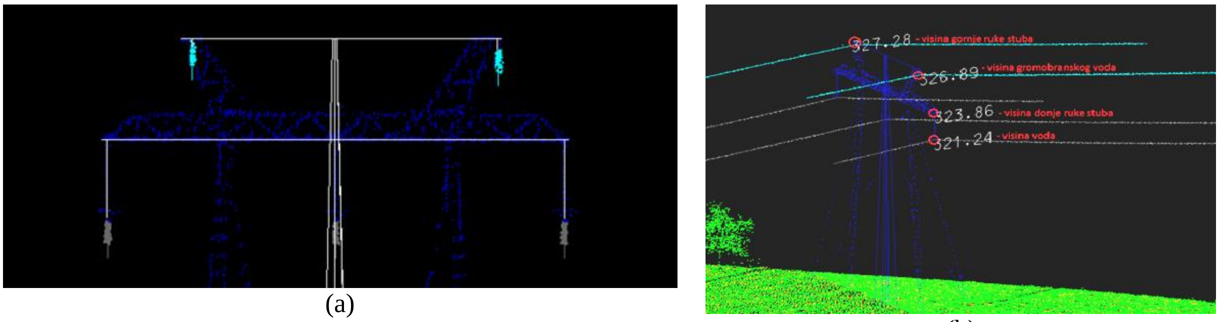
Figure 5. Water pipes (a) photo of a shaft with water pipes; (b) 2D representation of water pipes; (c) 3D representation of water pipes

In the case of utility networks above the surface, such as powerlines, LIDAR technology can be used for 3D data acquisition. Several projects concerning LIDAR surveying of powerlines for the purpose of legalization have been undertaken (Popović et al., 2017). LIDAR point cloud for the area of the transmission lines together with orthophoto were used as a starting point in producing the valuable data for utility network cadastre. The processing of data implies the classification of the point cloud automatically and manually, as well as 3D and 2D vectorization of the poles and powerlines. The final result is the 3D vector in DGN format. Since the utility network cadastre in Serbia only supports 2D spatial data, 2D data was derived from it. This data was used as an input for the utility network cadastre. The conversion procedure from 3D to 2D implied making a longitudinal profile along a tangent field with corresponding descriptions, stations, angles, cultures, types of roads, rivers, channels and all objects located in the observed area. The procedure itself is not automated, but selection of appropriate tools can result with a projection of all desired or selected objects from 3D into 2D space. Output format is 2D DGN and 2D DWG. Figure 6 (a) shows photo of a pole with powerlines, while Figure 6 (b) shows 2D representation of powerlines. Figure 7 shows 3D representations of a pole (a) and powerlines (b).



(a) (b)

Figure 6. Powerlines (a) photo of a pole with powerlines; (b) 2D representation of powerlines



(a) (b)

Figure 7. Powerlines (a) 3D representation of a pole; (b) 3D representation of a pole with powerlines

In order to prevent loosing, such 3D data can be referenced as a spatial source (RS_SpatialSource). The Law from 2018 introduces the novelty that each property is identified with unique property number. This is particularly important to mark real estate in 3D data sources. This facilitates the search of the desired utility line in 3D data source. If providers of the proprietary solutions decide to go toward stronger GIS/CAD integration in 3D area, our research may be pointed in that direction.

5. METADATA

In order to establish a data access mechanism for 3D data in the utility network cadastre, a useful approach is to establish metadata catalogues and systematically describe 2D and 3D utility network datasets, until further development in this area enables more tight integration and mapping of rights in such 3D datasets. This approach, although simple, would allow systematic usage and maintenance of the data. The following listing shows an example of metadata for the extracted power lines dataset in the vector format:

(MD_Metadata)
metadataIdentifier: (MD_Identifier)
...
contact: (CI_Responsibility)
role: (CI_RoleCode) author
party: (CI_Organisation)
name: Republic geodetic authority
dateInfo: (CI_Date)
date:

DateTime: 20180725
dateType: (CI_DateTypeCode) creation
metadataStandard: (CI_Citation)
title: ISO 19115-1
version: International Standard
referenceSystemInfo: (MD_ReferenceSystem)
referenceSystemIdentifier: (RS_Identifier)
code: 4326
codeSpace: EPSG
identificationInfo: (MD_DataIdentification)
citation: (CI_Citation)
title: Power Lines
date: (CI_Date)
date: 2017-05
dateType: (CI_DateTypeCode) creation
…
abstract: Power lines extracted from LIDAR data
status: (MD_ProgressCode) completed
pointOfContact: (CI_Responsibility)
role: (CI_RoleCode) resourceProvider
party: (CI_Organisation)
name: Republic Geodetic Authority, Serbia
…
resourceMaintenance: (MD_MaintenanceInformation)
maintenanceAndUpdateFrequency: (MD_MaintenanceFrequencyCode) daily
resourceFormat: (MD_Format)
name: DGN
version: 8
descriptiveKeywords: (MD_Keywords)
keyword: Power Lines
keyword: LIDAR
keyword: classification
…
resourceSpecificUsage: (MD_Usage)
specificUsage: Obtained data can be used in cadastre, electrical control and energy management system.
…
resourceConstraints: (MD_Constraints)
useLimitation: ...
spatialRepresentationType: (MD_SpatialRepresentationTypeCode) vector
spatialResolution: (MD_Resolution)
equivalentScale: (MD_RepresentativeFraction)
denominator: …
language: eng
characterSet: (MD_CharacterSetCode) ucs2
topicCategory: (MD_TopicCategoryCode) utilitiesCommunication
topicCategory: (MD_TopicCategoryCode) planningCadastre
extent: (EX_Extent)
description: Serbia
geographicElement: (EX_GeographicBoundingBox)
…
resourceLineage: (LI_Lineage)
scope: (DQ_Scope)
level: (MD_ScopeCode) dataset
statement: Dataset is created using semi-automatic classification of point cloud data in order to extract valid 2D/3D cadastre data….

6. CONCLUSION

The paper provides an overview on how the utility network cadastre in Serbia is organized based on the Law on state survey and cadastre that regulates all geodetic practice in Serbia. It also emphasizes the issues that arise during the implementation of the Law and necessity to introduce unifying data model of real estate cadastre and utility network cadastre through the development of the extended Serbian LADM country profile. The paper describes examples of using 3D data for utility network cadastre and presents means for facilitating this data through linking with 3D spatial sources and usage of metadata. Future work will examine the possibilities of the integration of legal and 3D data and possibilities of identification of 3D spatial units in the utility network cadastre.

The use of 3D technologies for data acquisition in the utility network cadastre is relatively new and it is not yet in general practice. Considering the fact that the current workflow for the data acquisition in the utility network cadastre is based on deriving 2D data from 3D data, at this point of development we are analyzing the possibilities to make use of 3D data in the utility network cadastre, as well. After we reach the final conclusion and the technology reaches more mature level, the next step will be to propose implementation and standardization at a national level through the means of development of rule books for the procedures of acquisition of data, maintenance and quality assurance and possible amendments to the Law in years to come. Another important issue that needs to be addressed is the integration with GIS. Since our 3D data are mostly CAD oriented, we did not analyze the possibilities to use GML based formats such as CityGML Utilitiy Network ADE and LandInfra InfraGML. However, future work needs to assess the possibility to integrate with GIS systems and provide conversion mechanism.

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BIOGRAPHICAL NOTES

Ph.D Aleksandra Radulović is an Assistant Professor at Faculty of Technicial Sciences, University of Novi Sad, Serbia. She has published several papers in ISI journals and conferences. She has also participated in several research projects including GIS (geoportal) for the Ministry of Environmental Protection and Ecology of Serbia, Information system of the real estate cadastre for Republic Geodetic Authority of Republika Srpska, Information system of the real estate cadastre in Montenegro and Information system for user requests submission in the cadastral system in Republic of Serbia. Her domain of interest are Geographic Information Systems, Spatial Data Infrastructures, Service Oriented Architecture, Cadastral Systems, etc.

Ph.D Dubravka Sladić is an Assistant Professor at Faculty of Technicial Sciences, University of Novi Sad, Serbia. She has published several paper in ISI journals and more than 20 papers in international and national journals and conferences. She has also participated in several research projects and projects including design and implementation of cadastral information systems in Republic of Srpska in Bosnia and Hertzegovina, Montenegro and Serbia. Her domain of interest are Geographic Information Systems, Spatial Data Infrastructures, Service Oriented Architecture, Cadastral Systems, etc.

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