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Important Context for a 3D Cadastre

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Topographic Signs - Important Context for a 3D Cadastre

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Key words: Topographic Signs, Topographic Symbols, 3D Cadastre, Land Administration

SUMMARY

Utilities, buildings and infrastructure digital representations are very important set of spatial data for quality and sustainable spatial management and development of community in general. Many countries are on the way of the establishment of the 3D cadastre. Existing 2D cadastral systems are able to make gradual transition to 3D cadastre, but for the implementation of real 3D cadastre in many countries it is necessary to change the regulations. A *topographic sign or topographic symbol* is representation of a topographic object on map. In combination with other geodetic and cartographic products we can get to very useful information, often quite relevant in order to provide reference context for a 3D cadastre. Topographic signs on topographic maps and on other geodetic products give a representation of complex real-world situations that are not usually drawn in the cadastral maps. The real world, physical, objects as included on topographic maps, prove the context/ reference for the legal spaces. This is true for both the 2D, but perhaps even more for the 3D case. Performing an overlay, if needed after proper orientation, it is easy to combine geodetic and cartographic products in today's digital environment. Special attention is needed for the tunnels, overpasses, underpasses, bridges and other objects to be registered in 3D cadastre because their 2D cadastral description does not meet the needs of modern society. In case of 3D topographic data (e.g. 3D CityGML model), then it would also well possible to implement this into 3D cadastre and combine 3D legal spaces with the 3D real world items from the 3D topographical model. However, this combination/integration is usually not feasible with the cadastral plans (survey plans, field sketches) as those are not draws to scale (in both 2D and 3D).

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1. INTRODUCTION

Lot of developed countries are exploring the use of a 3D cadastre system because these countries have well developed 2D cadastral system, which they further want to improve. Implementation of 3D cadastre is needed for better registration of ownership and other RRR's. Modern cadastral systems need to be designed and supported from three dimensional spatial perspectives. For the development of 3D cadastral system of any country a good foundation is ISO 19152, LADM (Land Administration Domain Model) which in its core provides registering 3D situations from the real world and can be applied in the development of new 3D cadastral systems, but also in the transition from the existing 2D and 2.5D cadastral systems into 3D cadastral systems.

The growing densification of urban land-use is consequently increasing situations of vertical stratification of rights. Traditional 2D cadastral models are not able to fully handle spatial information on those ownership rights in the third dimension, thus 3D cadastre has been attracting researchers to better register and spatially represent real world overlapping situations (Almeida et al, 2014). In the last couple of decades, there has been an increasing demand for property development in urban areas, resulting in the division of property ownership so that different owners can own delimited space on, above or below ground surface. Two-dimensional cadastral data cannot meet the modern needs of land management and land usage. It is essential to introduce the 3D cadastre (Choon and Seng, 2013). The limited advances in full 3D cadastres implementations throughout the world might be explained by the fact that the implementation of a 3D cadastre requires close collaboration between legal and technical experts in a empirical environment to understand the impact of each other's domain (Stoter et al, 2012).

Humans have been occupying space and time. Land administrators have been able to reasonably manage decisions about the occupied space. However, 3D modelling of spatial units provide better information for improved land management.

The solutions for registration of rights with 3D characteristics are very different. Broadly, one can observe that apartments are registered with drawings in the deed registration. But a true and complete 3D registration in the cadastre, supporting 3D at all stages (from survey via registration and storage in cadastral database to dissemination), does not exist anywhere. However, different countries have operational solutions supporting at least in part the 3D cadastre. Some notable examples are: Queensland, Australia (registering 3D volumetric parcels from the survey plans), Shenzhen, China (storing 3D volumetric parcels in the cadastral database) and Spain (representing 3D apartments by using a standard height per floor layer, see van Oosterom et al, 2014).

A *topographic sign or topographic symbol* is cartographic / symbolic representation of a topographic object on map. In combination with other geodetic and cartographic products we can get to very useful information, often quite relevant reference for a 3D cadastre.
Determining the height or third coordinate (Z) has never been easier thanks to the use of GNSS technology in geodetic practice. Many countries have developed networks of permanent GNSS stations that surveyors use to easily obtain very precise 3D coordinates in real time. This paper describes the complex real world situations (overlapping on same x,y location of natural objects with those built by man) in terms of context that topographical signs can provide in establishment of 3D cadastre. Examples from Croatian land administration system that affect the registration in 3D cadastre are analysed (tunnels, bridges, overpasses, underpasses, traffic loops, and utility cadastre).

This first section (introduction) overviews the 3D cadastre and its development during the last 16 years. The second section deals with 3D topographical signs (in the context of the Croatian State Geodetic Administration), while the third section describes the link between topographical signs, cadastral plans (maps) and cadastral registry entries. The fourth section deals with three-dimensional GNSS measurements that can significantly improve enrolment from existing 2D cadastral records. The paper ends with conclusion.

2. 3D TOPOGRAPHICAL SIGNS

Topographic signs on topographic maps and on other geodetic products (e.g. cadastral maps, field sketches, elaborate on partition of real property, etc.) give a representation of complex real-world situations that are not usually drawn in the cadastral maps. The next subsection provides some background on the State Geodetic Administration. This is followed by subsections presenting different types of 3D topographical signs: buildings, bridges, and other cases.

2.1 State Geodetic Administration

Croatian State Geodetic Administration (SGA) Geoportal is the central place to access spatial data and one of the basic elements of National Spatial Data Infrastructure. State Geodetic Administration is a public administration organisation performing administrative and expert tasks in the fields of geodesy, cartography, cadastre and photogrammetry, and is concerned with the establishment of a national spatial data infrastructure, digitisation of cadastre and geodetic-spatial system, official state mapping (1:5000, 1:25000, 1:100000, 1:200000), geodetic documentation, statistical data about real property cadastre, spatial units and utilities, and geodetic-cadastral activities related to the state border. National Spatial Data Infrastructure (NSDI) is defined as a set of technologies, measures, standards, implementation rules, services, human resources and other factors enabling the efficient integration, management and maintenance of the sharing of spatial data for the purpose of meeting national and European-level needs, which will be an integral part of the European Spatial Data Infrastructure defined by the INSPIRE Directive (URL 1).

In the period 2013-2015 Croatian State Geodetic Administration has implemented EU financed project “Support to the establishment of the components of the Integrated Land Administration System (ILAS) in the State Geodetic Administration - Instrument for Pre-Accession Assistance for Croatia - IPA 2010”. In this project an upgraded Croatian SGA Geoportal was done. SGA Geoportal represents one of the cornerstones of National Spatial Data Infrastructure (NSDI), disseminating spatial datasets under the jurisdiction of the SGA. Upgraded Geoportal is based on the same underlying technology platform as the previous one, but it was completely rebuilt with added new complex functionalities, new data services and an all new design. One of the biggest changes from the earlier version of Geoportal is the inclusion of user registration with several different user types. Depending on the user type, different functionalities and services are available. Major attention was addressed to the access security model and refinement of the SGA Geoportal Metadata subsystem. Data dissemination was implemented through the use of standard OGC services (WMS, WMTS, WFS and WCS) thus allowing their use in other systems as well. Integrated web viewer provides direct access to spatial datasets for general public, while reuse of web services will greatly facilitate the adoption of spatial data in other institutions and organizations. Also in this project the migration of alphanumerical database into the new GIS system was done. Around 1.600.000 house numbers and buildings spatially recorded were migrated from previous to the new system. Business and graphical web services developed, allowing easier access to address and organizational spatial units of the Republic of Croatia through the SGA Geoportal.

By changing topographic and cadastral maps scale with selecting different maps on SGA Geoportal (1:5000, 1:25000, 1:100000, 1:200000) or cadastral maps (from 1:1000 to 1:5000) we have access to 3D real-life situations that are already registered in the land administration system.

2.2 Buildings (3D situations from real life)

In Croatian land administration there are special topographic signs (Figure 1) for 3D situations such as overlapping buildings with other structures (such as underpasses, overpasses, roads or other parcels with projections (ancones) of building parts). Ancon is console or bracket, typically with two volutes, that supports or appears to support a cornice.

Models of physical objects resulting from observation in the field may differ from legal object boundaries. These differences between "facts in the field" and "facts in the documentation" can often be an obstacle for the realization of the various rights related to land administration. It is important that buildings have been registered in the official registers (cadastre and land registry) in a way that they accurately depict the actual state of real property. Thus we have "spatial objects", "legal objects" and other categories such as "economic objects"

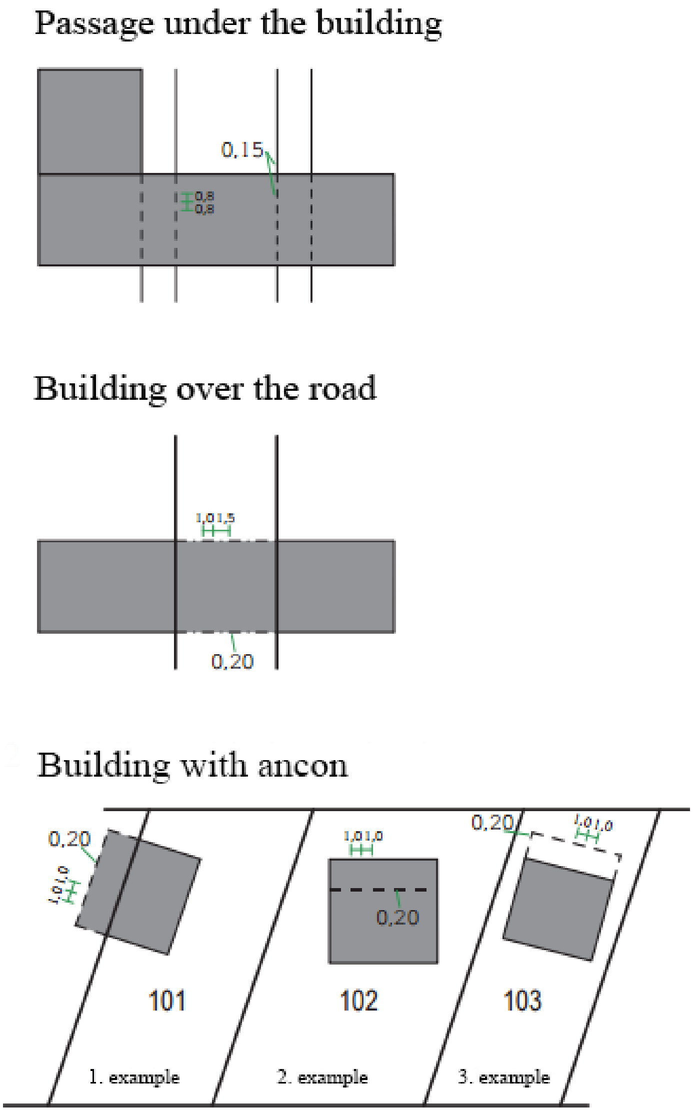

Figure 1. Different 3D cadastre situations in the Croatian Land Administration System and their official representation on the cadastral maps for scales 1:500 to 1:2000 (Official Gazzette 2011)

There are special signs that represent underground buildings on cadastral and topographic maps (Figure 2). Cadastre can register underground buildings only on the cadastral maps and in the land database, but without area information, while in the land registry area can be registered. A lot of new underground buildings were built in Croatia during last two decades and that is the reason why State Geodetic Administration of the Republic of Croatia is considering a new regulations which will be able to register underground buildings with area and other attributes into the cadastre.

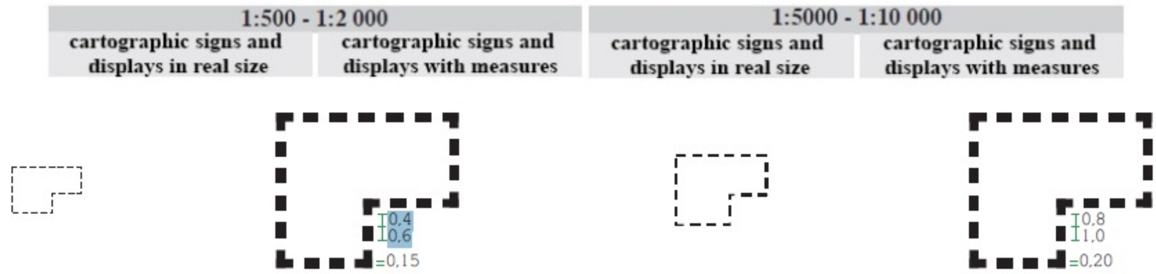

Figure 2. Topographic signs for underground building (Official Gazzette 2011)

In Croatia at this moment there are no official records that can provide complete information about all buildings as spatial objects. Cadastre and Land registry are the only official and systematically maintained registers which contain data on real property, which also includes buildings. Condition, integrity and structure of data collected on buildings and maintained in these registers does not allow insight into the state and basic characteristics of certain buildings and overall condition of buildings in the entire country. Therefore, one of the strategic objectives of the State Geodetic Administration is establishment of multipurpose registration of buildings to provide such data and information. Implementation study of the registration of buildings should answer how to establish institutional, legislative and financial framework and propose the structure of the data model and technical standard for the information system of such cadastre. Also, this study should provide short-term and long-term strategic guidelines regarding system architecture, data model, specific needs of stakeholders, required legislation, the benefits delivered by such system and financial resources needed for its establishment and maintenance (URL 2).

2.3 Bridges

A bridge is a structure built to span physical obstacles without closing the way underneath such as a body of water, valley, or road, for the purpose of providing passage over the obstacle. There are different topographic sign designs that each serve a particular purpose and apply to different situations. There are few different types of bridges in the Croatian Land Administration System (Figure 3).

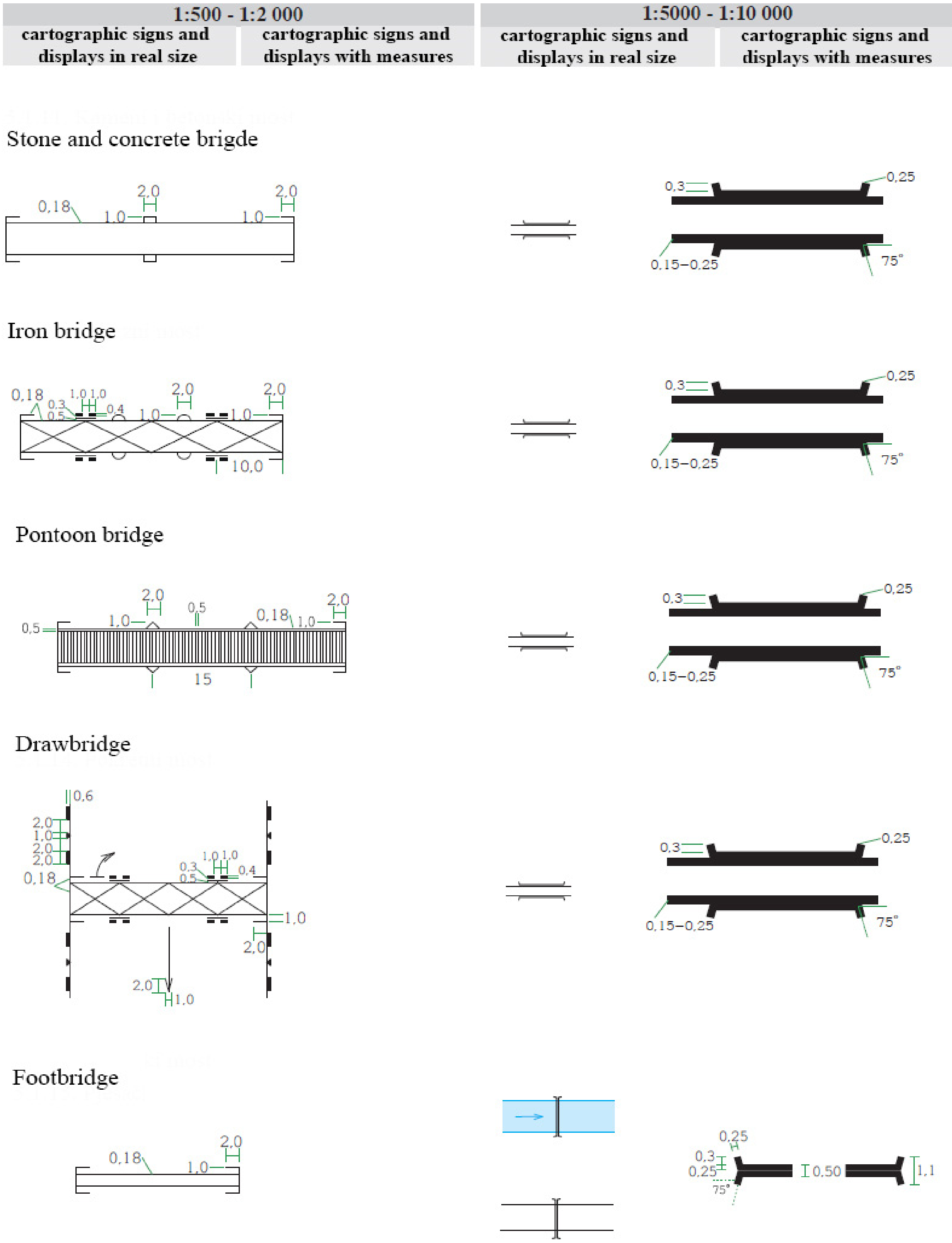

Figure 3. Bridges representation in the Croatian Land Administration System (Official Gazzette 2011)

2.4 Other real-life 3D situations

Other 3D real-life situations such as pedestrian passageways are also regulated by the geodetic and cadastral legislation (Figure 4). Also tunnels, pipelines, overpasses, etc. are good examples of potential 3D objects. Dimensions of topographic signs are expressed in millimeters. Topographic signs are different for specified scale of cadastral products. There are often categorized into two groups (from 1: 500 to 1: 2000 – for cadastral maps) and (from 1:5000 to 1:10000 – for topographic maps).

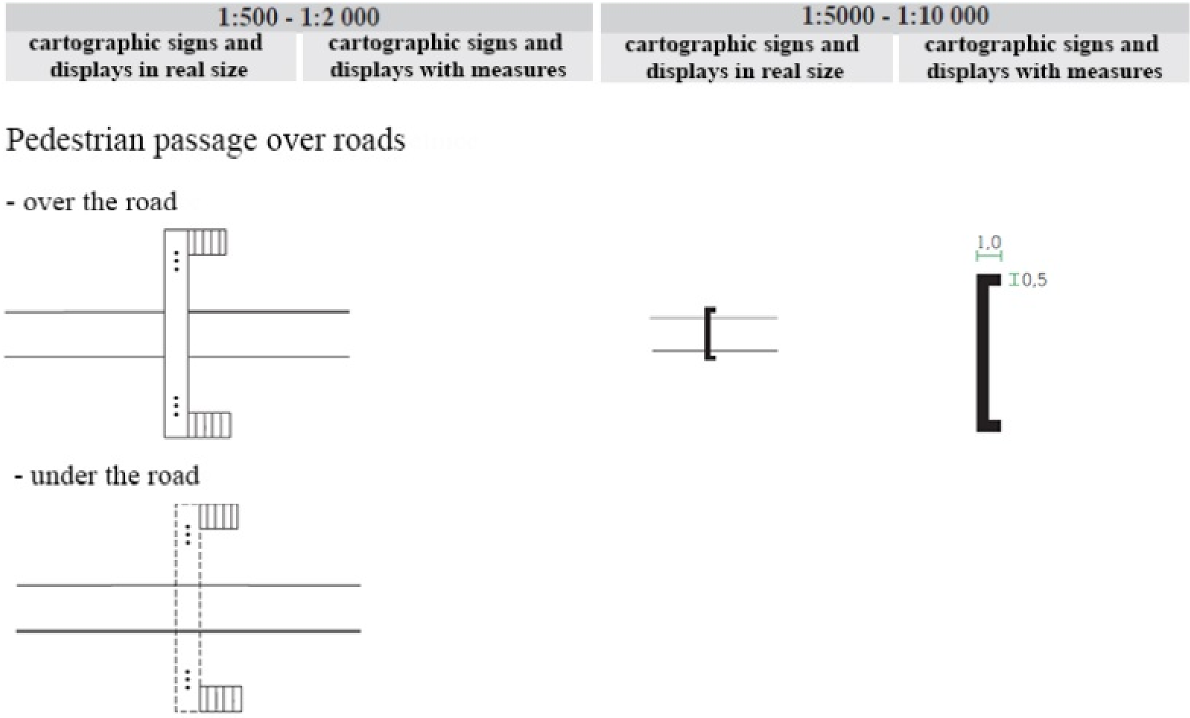

Figure 4. Pedestrian passages in 3D cadastre

Road viaducts (overpasses) are often found on highways and junctions near highways (Figure 5). There are also often founds in cities.

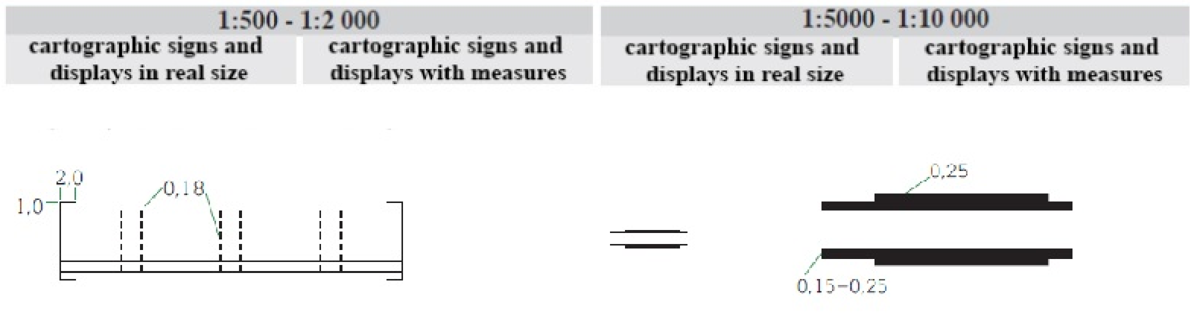

Figure 5. Road viaduct (overpass)

3. LINK BETWEEN TOPOGRAPHICAL DATA AND CADASTRAL DATA

The base register for large scale topography forms an excellent context for 3D cadastral solutions as the 3D cadastral parcels (3D legal spaces) are often related to (planned) physical objects; such as buildings, tunnels, pipelines and other constructions. For reference purposes the 3D legal objects and their 3D physical counterparts should be associated. This implies two aspects:

- the 3D physical object descriptions (topographic objects) should exists, which is not obvious as in most countries the large scale topographic base map is still 2D, and
- the topographic objects should be usable and reference-able even when the data is maintained by other organizations.

The Land Administration Domain Model (LADM, ISO 19152) supports Spatial Data Infrastructure (SDI) implementations as the information infrastructure requires in the model: unique ID numbers for all objects, full database history (versioning), and blueprints of external classes (such as the topographic objects: buildings, tunnels, pipelines, etc.). This besides the fact the standard provides the semantics of land administration data to other users within the SDI (Jeong et al, 2012). In the remainder of this section to case studies are presented: 1. road tunnel trough a mountain, and 2. a pedestrian tunnel below a road.

3.1 Case study 1 - tunnel

Sveti Rok tunnel is a double-tube tunnel located on the Sveti Rok - Maslenica Section on the Zagreb - Split - Dubrovnik Motorway. The length of the left tunnel tube is 5,679 m and the length of the right one is 5,670 m. The traffic flow runs through both tubes, separately for each traffic direction. The north tunnel portal is placed at 561 m above sea level and the south portal at 510 m above sea. The tunnel passes trough Velebit mountain in the corridor of Mali Alan mountain saddle (Figure 6).

Figure 6. Road tunnel Sveti Rok

Example from the Croatian Land Administration System is on the figures (

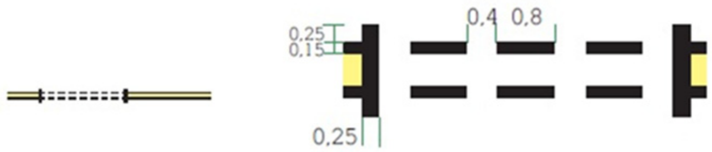

Figure 7) and (Figure 8). The tunnel, which was built under many cadastral parcels, in a vertical sense it would belong to those cadastral parcels. Functionally, it is permanently connected to the land where the entrance to the tunnel is, and not to the cadastral parcels that extend above it. Therefore, according to the legal rule, as the tunnel is permanently connected only to the land with entrance, it makes one property.

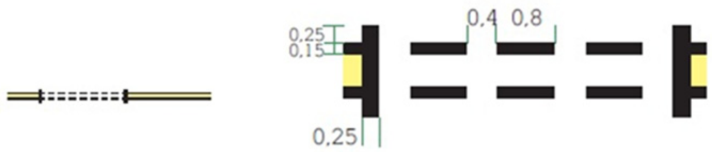

Figure 7. Topographic sign for the road tunnel (for scales 1:20000 to 1:25000)

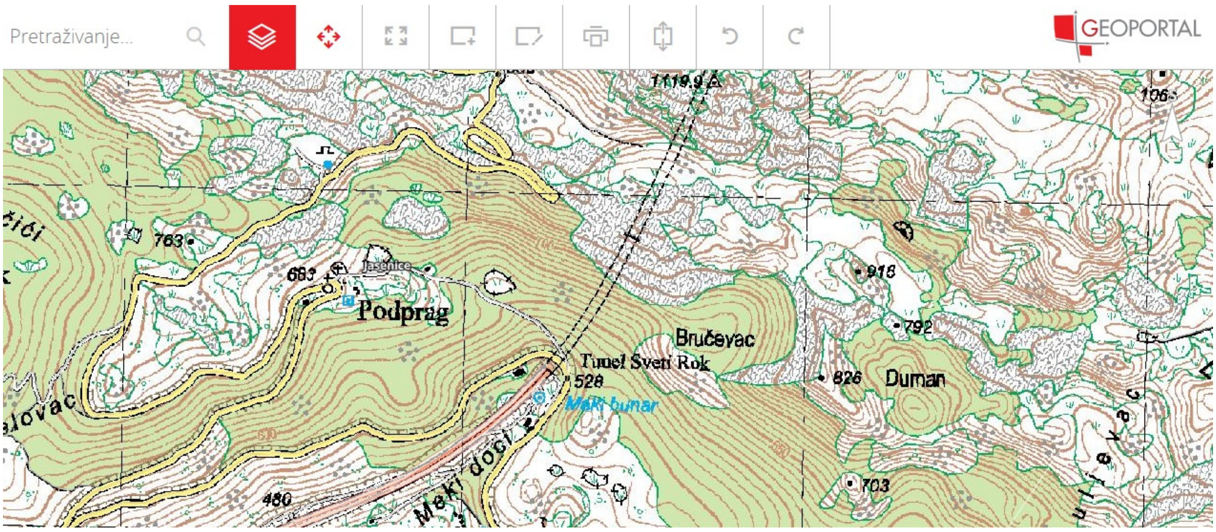

Figure 8. Tunnel on the Croatian State Geodetic Administration Geoportal (layer: Topographic Map 1:25000)

3.2 Case study 2 - pedestrian passage under the street

In Croatia, pedestrian passages under roads are situated mainly in large cities. Smaller towns usually do not have these 3D situations (Figure 9).

Figure 9. Pedestrian passage under the street, Zagreb, Savica (source: www.d-a-z.hr)

Figure 10. Pedestrian passage under the street, Zagreb, Savica on the SGA Geoportal - digital ortophoto image overlapped with digital cadastral map (URL 1)

4. GNSS

With the rapid development of spatial information infrastructure in US, Europe, Japan, China and India, there is no doubt that the next generation Global Navigation Satellite Systems (GNSS) will improve the integrity, accuracy, reliability and availability of the position solution as basis for efficient 3D spatial data acquisition. GNSS is becoming an essential element of geospatial infrastructure and consequently part of our daily lives (Zhang et al, 2009).

Accuracy analysis of GNSS-RTK (real-time kinematic) measurements has enough to apply to third-order control points and parcel relocation survey. Work procedure for establishing control network is efficient rather than traditional method, traverse survey using total station equipment. GNSS-RTK system can determine 3D position with centimetre level accuracy in real time so that registration of building height, underground facilities and etc. (Lee et. al. 2012).

Determining the height of GNSS-leveling with positional surveying (coordinate: X, Y) can significantly contribute to future registration of tunnels in the official registers (cadastre and land registry) because the registration in the cadastre usually requires less accuracy than is provided for the engineering geodesy. Certainly GNSS-leveling is suitable for surveying entry and exit of tunnel portal, while for surveying the interior of the tunnel is still necessary to use the terrestrial surveying methods (Vučić 2015).

Also the registration of bridges in the cadastre usually requires less accuracy than is provided for the engineering geodesy and we can conclude that network-based real-time kinematic GNSS method is optimal for the spatial registration of bridges in the official registers (cadastre and land registry).

5. CONCLUSION

The real world, physical, objects as included with specific signs (cartographic symbols) on topographic maps, prove the context/ reference for the legal spaces. This is true for both the 2D, but perhaps even more for the 3D case. Performing an overlay, if needed after proper orientation, it is easy to combine geodetic and cartographic products in today’s digital environment. Special attention is needed for the tunnels, overpasses, underpasses, bridges and other objects to be registered in 3D cadastre because their 2D cadastral description does not meet the needs of modern society. In case of 3D topographic data (e.g. 3D CityGML model), then it would also well possible to use this into 3D cadastre and combine 3D legal spaces with the 3D real world items from the 3D topographical model. However, this spatial overlay based combination/integration is usually not feasible with the cadastral plans (survey plans, field sketches) as those are not draws to scale (in both 2D and 3D). They need explicit (manual) links to relate these 3D legal spaces with the 3D real world items.

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BIOGRAPHICAL NOTES

Nikola Vučić graduated in Geodesy from the University of Zagreb, Faculty of Geodesy. In 2015 he received a PhD from the University of Zagreb for the thesis "Support the Transition from 2D to 3D Cadastre in the Republic of Croatia". He is the Head of the Department for Administrative and Professional Supervision at the State Geodetic Administration of the Republic of Croatia. His main research interests were and still are land administration systems, cadastres and geoinformatics. He is a member of the Croatian Geodetic Society.

Peter van Oosterom obtained an MSc in Technical Computer Science in 1985 from Delft University of Technology, the Netherlands. In 1990 he received a PhD from Leiden University. From 1985 until 1995 he worked at the TNO-FEL laboratory in The Hague. From 1995 until 2000 he was senior information manager at the Dutch Cadastre, where he was involved in the renewal of the Cadastral (Geographic) database. Since 2000, he is professor at the Delft University of Technology, and head of the 'GIS Technology' Section, Department OTB, Faculty of Architecture and the Built Environment, Delft University of Technology, the Netherlands. He is the current chair of the FIG Working Group on '3D Cadastres'.

Danko Markovinović is director general at the State Geodetic Administration of the Republic of Croatia. In 2009 he received a PhD from University of Zagreb for the thesis "Gravimetric Reference System of the Republic of Croatia". He has been employed at the Faculty of Geodesy of the University of Zagreb since 1995 till 2012. He is chartered geodetic engineer at Croatian Chamber of Chartered Geodetic Engineers. He is vice-president of the Council of European Geodetic Surveyors.

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