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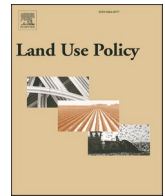
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Registration of apartments and office spaces in 3D land administration – A case study in Croatia

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ABSTRACT

Due to the needs of modern society, cadastral systems should be designed to support three dimensional (3D) spatial data. One of many possible approaches for implementing a 3D cadastre, in countries such as Croatia, is to establish a Building Register as a transitional register between 2D and 3D cadastral systems, where data about buildings and infrastructure would be collected, gradually adapted to the data model of 3D cadastre, and finally migrated to the 3D cadastre database. Sources for establishing the Building Register can be based on the records of state surveys, the register of administrative units, the land book, data managed by local and regional self-government units, data from construction documentation according to special regulations in the field of spatial planning, data managed by the building and infrastructure managers, as well as from other sources. A significant element of the 3D cadastre would be the inclusion of representations of buildings and units of use, as well as public utility infrastructure and complex spatial real-life entities (e.g., bridges, tunnels, overpasses, underpasses, overlapping of constructed objects with natural facilities, large shopping malls with more underground and overhead floors etc.). This paper presents a conceptual model of a 3D cadastre in Croatia by establishing the Building Register with focus on unit of use of real properties, namely apartments and office spaces. The paper also summarizes the current situation regarding the Croatian Land Administration System (LAS) and proposes a conceptual model for modelling unit of use of real properties. Additionally, a proposal is made herein to assign unique identifiers to buildings and their parts in a logical manner which would be intuitive and clear to citizens of Croatia, citizens of European Union and citizens of Croatia neighboring countries. The proposed methodology of determining unique identifiers could provide the means for easier navigation in 3D space and better understanding of spatial information by lay citizens, by institutions or emergency services.

1. Introduction

Even though in recent years there has been a number of papers dealing with different methodologies to establish 3D cadastral systems (Radulović et al., 2017; Sladić et al., 2018; Rajabifard et al., 2018; Vučić et al., 2017, 2020), actual implementations do not follow these advances.

The methodology used in this paper is based on the design science research model described in Hevner and Chatterjee (2010). This includes the design, construction and evaluation of a Croatian-relevant 3D cadastral model based on an analysis of Croatia's particular needs (Fig. 1).

Nowadays, it is extremely important to have good quality geocoding

data for different spatial analyses. Also there are at least five areas for future research on geocoding (Zandbergen, 2009).

Different countries from Europe, transitional countries, and other countries have also dealt with problems developing 3D cadastral models within the context of their jurisdictions. These include, for example, China, Greece, the Netherlands, and Turkey (Ying et al., 2019; Gkeli et al., 2021; Broekhuizen et al., 2021; Gürsoy Sürmeneli et al., 2022; Guler, 2022).

In this paper, a methodology for the implementation of a 3D cadastre, by using a transitional register between 2D and 3D cadastre called "Building Register", is presented. The paper also presents an extended version of the model previously developed in (Vučić et al.

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2020) which is applied to units of use of buildings.

The proposed model is presented from the perspective of a cycle of system development: Design domain, requirements, design, construction, evaluation, and rigor (i.e. new knowledge). This paper is therefore organized as follows: Section 2 describes the research background. Section 2 describes the design domain. Section 3 describes of the process of registering buildings in Croatia and is the requirements section for building the model. Section 4 describes the process of establishing the Croatian 3D cadastre, and is the “build” portion of the model development. Section 5 presents practical examples of implementing the model as a means of evaluating the design. Section 6 provides conclusions, including confirmation of what new knowledge is gained from the model development, and recommendations for future research.

2. Background

This section describes the design domain in the International context and for the Republic of Croatia.

2.1. International

Cadastral systems across the world are in different stages of development. Most cadastral systems are based on two-dimensional land parcels and use floor blueprints, cross-sections and isometric diagrams for representing 3D properties. This might be related to jurisdictions’ limited abilities to properly visualize 3D properties. However, there are exceptions such as Australia where 3D properties can be registered based on 3D volumetric survey plans.

Nevertheless, the main aim of using 3D models is to provide a more precise description of a real estate. The right of ownership can be transferred on 3D properties as it is the case with traditional 2D properties (i.e. parcels). The project COST Action G9 ‘Modelling Real Property Transactions’ (Zevenbergen, 2007) tries to recognize generalized stages of the transferring ownership procedures and gives examples from Slovenia and Sweden. Ferlan et al. (2007) recognized the following stages of transferring ownership: land use policy (i.e., checking who has

the right to sell/buy a property); marketing activities (which usually involves real estate agents); pre-contracting/contracting (i.e., signing a contract between buyer and seller); and registration (whereby the transaction becomes transparent and usually protected against third parties). The transfer of ownership in Slovenia is similar to the situation in Croatia while the Swedish case has slightly different timing of activities. For example, in Sweden, purchase money is paid simultaneously with the signing of the contract while in Slovenia and Croatia the purchase money is often paid after the contract of sale has been signed.

With the development of 3D model-related technologies, especially regarding the design and managing of the overall lifecycle of buildings by using the concept of Building Information Modelling (BIM) with 3D models (Ying et al., 2019; Gkeli et al., 2021; Broekhuizen et al., 2021; Gürsoy Sürmeneli et al., 2022; Guler, 2022), and the improvement of digital and web systems, the advantages of automated building permits issuing systems became apparent in many countries. The process can also be faster and more transparent (Noardo et al., 2020). Also, such models could be used as one of the sources for the implementation of 3D cadastre and provide clear visualization of 3D properties.

Benefits of using 3D data are manifold. Cities are also increasingly adopting the development of 3D city models. Providing further value and additional utility over 2D geo-datasets, 3D city models are becoming ubiquitous for making decisions and for improving the efficiency of governance. For instance, some local governments use 3D city models for urban planning and environmental simulations such as estimating the shadows cast by buildings, investigating how noise from traffic propagates through a neighborhood, and predicting how much solar radiation the roof of a building receives (Biljecki, 2017). For the processes that include 3D information, the choice has to be made regarding which specifications will be used and how representations of 3D spatial units will be resolved (Sladić et al. 2020). In the case of Poland, Karabin presents rules concerning the registration of various untypical 3D objects located within the city of Warsaw (Karabin, 2012).

In Slovenia, for example, data currently available in the cadastral system can be used for a 3D real property cadastre and its graphical representation in the 3D environment, although some additional data is

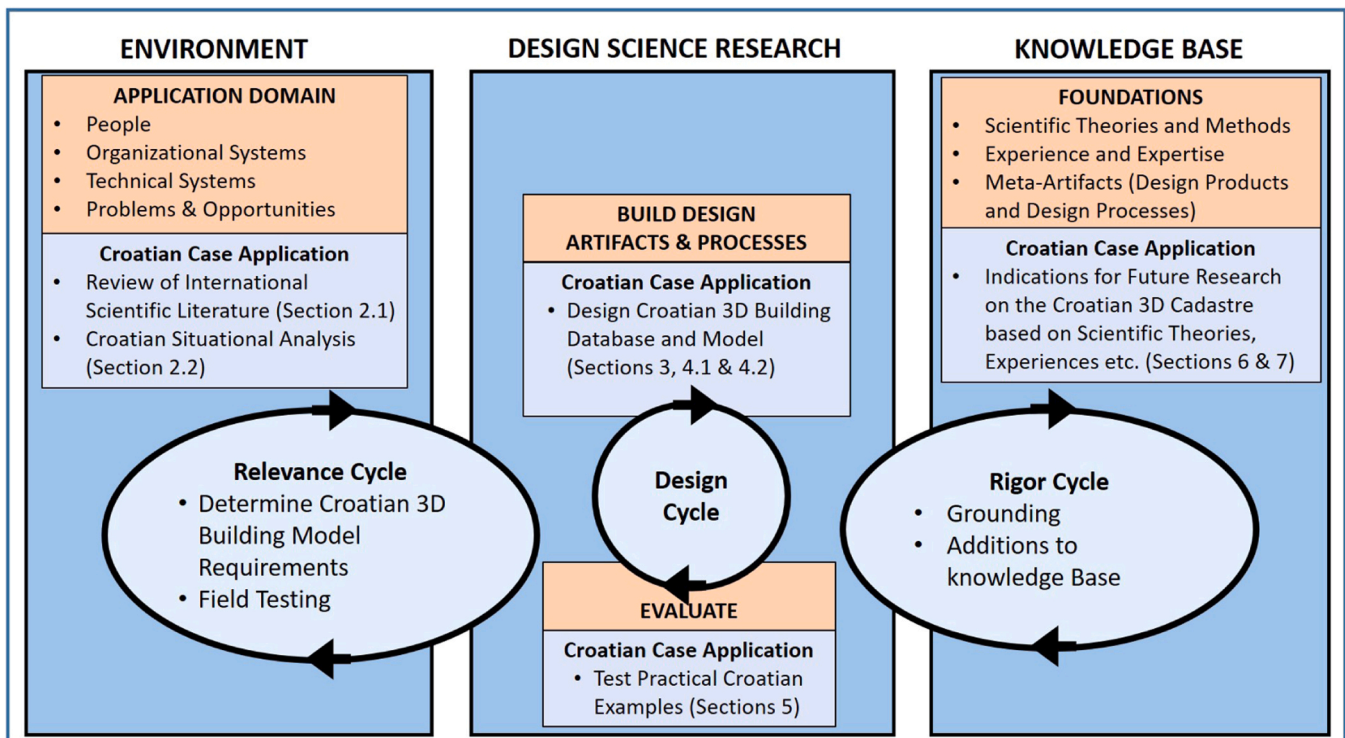


Fig. 1. Research methodology (After Hevner and Chatterjee, 2010).

needed. The minimum data required could be provided already through the current cadastral procedures (Drobež et al. 2017). The Slovenian land administration system (like in neighboring countries such as Austria and Croatia) is based on a dual registration system consisting of a cadastral and a land registry part. The cadastral system, operated by the Surveying and Mapping Authority (SMA), consists of the Land cadastre and Building cadastre. The Building cadastre is a relatively new system in the Republic of Slovenia, introduced after 2000 and aims at providing detailed data on buildings and parts of buildings needed for the registration of ownership and other rights on parts of buildings in Land registry. The Land registry, which is linked to the cadastral system, is operated by the Court (Tekavec et al., 2021). The Slovenian land administration system does not have a lot of mismatches between the cadastre and the land registry.

In Serbia relevant research propose a new system for a 3D cadastre based on Land Administration Domain Model (LADM). The current Serbian cadastral data organization fits into a LADM-based data model without losing any relevant information (Radulović et al. 2017). The land registry in Victoria, Australia, is investigating the technical requirements for implementing a 3D digital cadastre (Shojaei et al., 2017). The project '3D Cadastral Survey Data Model and Exchange' (3D CSDM) was to develop a harmonised data model that covers all cadastral survey data components required by the nine Australian- and New Zealand cadastral agencies. This includes both 2D and 3D elements (Haanen, 2021). Project continuation is being facilitated by development of a harmonized data model capable of transferring 3D Digital Cadastral Data between jurisdictions and surveyors in a standardized manner (Haanen et al., 2023).

Building information modeling/Industry Foundation Classes (BIM/IFC) is increasingly entering the field of land administration modernization and is the subject of relevant research by many authors (Guler et al., 2022, Alattas et al., 2021, Sun et al., 2021, Jamil et al., 2017).

Research on the potential value of 3D spatial data usage for particular jurisdictions sometimes outpace actual efforts to implement them. This has not inhibited local researchers from designing technical specifications for those jurisdictions. For example, although the development of a 3D cadastre in Trinidad and Tobago has not yet been officially adopted, local researchers have conceptualized 3D specifications with the suggestion that a 3D cadastre be implemented for some dense urban areas as a pilot project (Griffith-Charles and Sutherland, 2013).

In Malaysia's development of a 3D Cadastre, a Unique Parcel Identifier (UPI) is a unique way of identifying land parcels and it is used among the government and private agencies such as local authorities, taxes department etc. The purpose of creating the UPI is to identify the structural form and physical characteristics of each parcel of land (lots). Each parcel sets a consistent code structure (Hassan et al., 2011). In Taiwan, some measures of improvement are proposed for the government and organizations of condominium management (Hseih, 2009). In Saudi Arabia, each building has an identifier consisting of building number, postal code and an additional number. If the building has several property units such as apartments or offices, all units are numbered sequentially. (Alattas et al., 2021). Li et al. (2016) states in their paper that each condominium unit must have a unique identifier in order to associate legal objects with their physical counterparts, but without going into the details about how these identifiers should be composed or assigned.

2.2. Croatian background

From the model development perspective, this section provides the design domain for the proposed model. In the Republic of Croatia, different registers and official databases on land and interests emerged where redundancy between different sources has become obvious (Mader et al., 2015). Also, in Croatia mismatches between its cadastre and land book occur very often. One of the possible reasons for the introduction of these inconsistencies relates to the country's

sociopolitical development. Croatia was under a communist regime until 1990 where the right of ownership was neglected since everything was owned by the state, i.e. its people (Roić, 2012). This caused the situation where the cadastre has more relevant data about real properties and the land book often has invalid data. In these cases, very often, land book contains old records from the time of Austro-Hungarian monarchy. Another reason for inconsistencies in data about real properties is of a technological nature. Registers were managed independently, which has also introduced certain inconsistency and redundancy. Currently, technical solutions exist to reduce redundancy and improve interaction between these registers in order to gain new values and establish Multipurpose Land Administration Systems and a 3D cadastre as well. In the Republic of Croatia, the cadastre manages data on the position, shape, and area of real properties, while the land book manages data on rights, restrictions, and responsibilities (Vučić et al. 2017). Conceptual model of Land Administration Domain Model (LADM) covers both sides (Cadastre + land book). The aforementioned mismatches are partially mitigated by very good digital platforms (e.g., (i) a joint Information System of Land Registry and Cadastre; and (ii) a system of digital geodetic reports) which enables all land administration data to be permanently and publicly available not only to Croatian citizens but also to the whole world. This facilitates persons, whose real estate data has not been accurately described, to arrange for a surveyor or a lawyer to assist in remedying the situation. In addition, the Republic of Croatia has significantly organized a new cadastral surveys process, through which data on real property are managed both geometrically and legally.

Research on the potential value of 3D spatial data usage for particular jurisdictions sometimes outpace actual efforts to implement them. This has not inhibited local researchers from designing technical specifications for those jurisdictions. For example, local Croatian researchers have described a conceptual model for establishing a 3D cadastre through cadastral resurveys (Vučić et al. 2020).

While 3D spatial data have different applications and can bring added value in comparison to 2D spatial data, collection and maintenance of such data remain challenging. Existing workflows for registering new buildings can be adapted for 3D cadastre. Existing buildings can be registered in 3D cadastre from various existing official sources and registers. A methodology for the implementation of a 3D cadastre, by using a transitional register between 2D and 3D cadastre called "Building Register", is currently being tested in the Republic of Croatia. The idea of a Building Register is to collect information about the buildings from different registers and adjust them for the 3D cadastre. In the Republic of Croatia, this is stipulated by the State Survey and Real Property Cadastre Act (Official Gazette 2018). Following these activities and changes in the legislation, the Land Administration Domain Model (LADM) is also extended to develop a conceptual model for registering apartments and office spaces. A methodology for assigning logical unique identifiers to unit of use of real properties, more specifically buildings, is also discussed.

First, the starting points for developing a conceptual model for registering unit of use is described. It is based on the LADM (Lemmen et al., 2015) and its Croatian country profile (Vučić et al., 2013). The LADM became a formal International Standard in 2012, published as ISO 19152 (International Organization for Standardization, 2012). Lemmen et al. (2013) summarize the goals of LADM:

- Establishment of a shared ontology implied by the model.
- Support to the development of the application software for Land Administration.
- Facilitation of cadastral data exchange with and from a distributed Land Administration Systems.
- Support to data quality management in Land Administration.

The first version of the Croatian LADM profile was developed in 2013 to respond to the need of modelling specific situations in the Republic of Croatia, which were mentioned in the introduction. The Croatian

HR_UsageTypeLand and HR_UsageTypeBuilding of class HR_SpatialUnit (Fig. 2), have values according to code lists created according to the Regulation on Land Cadastre (Official Gazette 2007).

LADM and the Croatian country profile support modelling of 3D spatial units, including building and building parts. In a recent work (Vučić et al. 2020) proposed a LADM-based conceptual model for collecting more information about buildings and their parts (Fig. 3). In this paper this model has been extended and tested in the case of buildings and their parts, specifically in relation to apartments and office spaces.

Each class in LADM, including spatial units has the attribute for storing unique identifier of a type "Oid". This data type is a complex datatype consisting of the namespace and unique identifier within the namespace. Currently, building units of use do not have publicly exposed identifiers to be placed on buildings to be used as a reference in daily activities such as delivering packages directly to the apartment door. In large buildings it may become a complex task to find a specific apartment since from one building entrance many apartments may be accessed. The unique identifiers that are being proposed in this paper are complementing the address of a building and contain a classification code which directly contains the floor number and apartment number within the floor. Currently, cadastre is maintaining most of the information that should be used in the unique identifiers such as the code of

cadastral municipality and unique building number within cadastral municipality. Since cadastral municipality borders are not changing frequently it was decided that it is more suitable for the unit of use identifier instead of the address of a building. Chapter 5 of this paper discusses the methodology for assigning unique identifiers to unit of use of real property. LADM supports assignment of unique identifiers to every object (data type Oid). Besides Oid, it is proposed to generate unique identifiers in an intuitive and practical manner so that they can be understood by any person. Furthermore, logical identifiers could help people, institutions, companies or emergency services when searching for a specific apartment in a large building. This approach is similar to the approach presented in (Alattas et al., 2021) with a difference being that the identifier in this paper is related to cadastral municipality while Alattas et al. (2021) have referenced the building identifier to a postal code. The reason why cadastral municipality identifier is used here is the fact that it is rarely changed, while addresses have changed more frequently in the past.

3. Registering Buildings in Croatia

This section describe the process of registering buildings in Croatia and is the requirements' section for building the model. Currently in

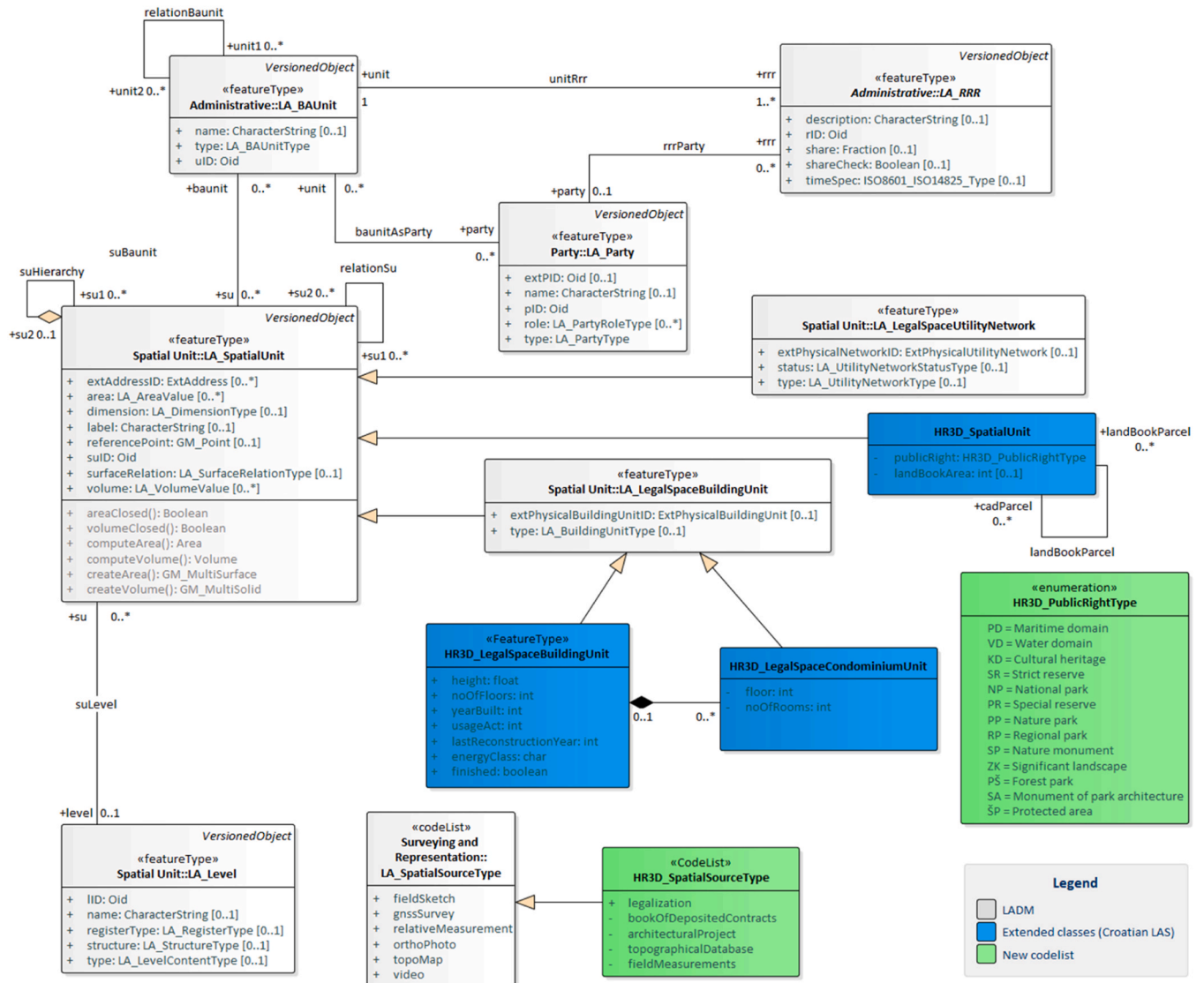


Fig. 3. LADM extension to support transition to 3D cadastre in the Republic of Croatia (Vučić et al. 2020).

Croatia, buildings are registered in the land book based on the information delivered from the cadastral office. The cadastral office receives geodetic reports from licensed private surveyors usually in digital form. This information is authoritative. Ownership of a unit of use of real property (e.g. an apartment or an office space) is formed through the registration in the land book. Such units of use may be registered if they constitute independent entities. The registration of ownership can be done by signing the contract, which has to be verified by a licensed notary. Then the notary sends the proposal for registering the right of ownership together with the contract to the land book in an electronic form. The described procedure is equal to the procedure in Slovenia as described in (Ferlan et al., 2007).

Units of use of real properties may include balconies, terraces, basements, and attics, under the condition that they serve exclusively a single unit of use. Land book registration of the units of use is not possible without the submission of a condominium report that must be prepared by an architect, a civil engineer, or a surveyor. In the cadastre, from the LADM perspective, the LA_BAUnit consists of one or more LA_LegalSpaceBuildingUnits as one real property object with its own RRR attached. The same procedure is commonly used in the land book to formally consolidate land which was often publicly owned with buildings constructed on the land. The building complex first needs to be subdivided into multiple LA_LegalSpaceBuildingUnits, which can be used to form the LA_BAUnits to be registered in the land book (adding the RRRs).

The report on condominium partition of real property establishes the size and shape of the common space and units of use of a single real property (apartment, office space, etc.) and establishes connections for reference purposes against the real property as a unit. Additionally, data about units of use of real properties must be technically processed, providing drawings of separate and common parts of real properties with the required labels and areas of these parts. A shared ownership contract must also be provided with the report on condominium partition.

In the last quarter of 2020, the State Geodetic Administration of the Republic of Croatia has started the procurement of Geoinformatics services for the needs of establishing a Building Register in the pilot area in Varaždin county. These services include the development of a methodology for collecting and processing data on buildings and the development of a multipurpose data model that will consist at least of the graphic basis of the Building Register, a set of graphic data and a set of alphanumeric data. Based on the approach from this Section, it is necessary to perform mass data collection and geoinformatics processing of data on all buildings in the pilot area in Varaždin county (Building Register project public procurement notice, 2020). The database should be established in order to provide integrated storage for alphanumeric and graphical (spatial) data on buildings. Processing of collected data, primarily topographical in nature, will be combined with data from other official records in order to build more complete 3D model of buildings. During the integration of collected data with already available data from official registers, the following registers will be primarily taken in the consideration: Joint land book and Cadastre Information System (real property cadastre/land cadastre data and land book data), the Address Register and local government units' databases. Local government units' databases contain useful information about area, number of floors and real owner of real property and/or unit of use, but their databases is usually in MS Excel format or in better case in some custom made application. Those databases are in general authoritative for local government unit's purposes. Prior to the initial data entry into the system, a quality control of already produced topographic or cadastral spatial data will be conducted in order to determine their usability for the establishment of initial database for the Building Register (topological control and integrity control) (Shojaei et al., 2017). Based on the established database, a set of business processes for maintaining the Building register will be defined. Finally, a multi-purpose Building Register information system will be implemented by creating a

web-based solution for editing and visualization (Shojaei et al., 2013) of attribute and graphic data on buildings (Radulović et al. 2017).

Fig. 4 summarizes the datasets that are being used as input datasets for the Building Register. Also, it lists related laws that should be amended in order to support the transition towards the 3D real property cadastre.

In the next section an initial conceptual model for buildings and their unit of use in the Building Register is proposed, which can be further transposed to 3D cadastre.

4. Establishing the croatian 3D cadastre

This section describe establishing the Croatian 3D cadastre, and is the "build" portion of the model development.

Previously, several papers were written about Croatian 3D Cadastre, covering initial analysis of the current situation (Vučić et al. 2017) and exploring options for upgrading Croatian LAS to the third dimension (Vučić et al. 2017, 2020; Vučić et al. 2015). In the Republic of Croatia, as in the rest of the world, the value of land in the urban regions is increasing and there is a trend towards the subdivision of property rights in three dimensions (Thompson and van Oosterom 2012).

The model presented herein includes new attributes related to buildings while attributes of unit of use are sufficient and taken from the previously developed model. Buildings are modeled as instances of the class *HR3D_LegalSpaceBuildingUnit* which is descendant class of LADM's *LA_LegalSpaceBuildingUnit*, which is a further descendant of the class *LA_SpatialUnit*. Unit of use are modeled as instances of the class *HR3D_LegalSpaceCondominiumUnit* (Fig. 5).

4.1. Data about buildings

In the Republic of Croatia many buildings are not registered in the cadastre even though it is prescribed by law. Formally, a building can be registered in the cadastre only if a party (usually the owner or the representative of owners in case of multi-residential buildings) submits a claim for cadastral registration. Technically, a building can be registered based on a geodetic survey report prepared by an authorized surveying company, and the cadastral office will review and verify the correctness of the report. Surveying companies are not restricted to use specific surveying methods, but the field surveying must be performed with following rule. The data quality of field measurements for breaking points of boundaries of cadastral parcels and buildings is determined by the confidence area for horizontal coordinates with 95% probability by the standard of positional accuracy up to 0.1 m (Official Gazette 2018). Currently, it is not permitted to register a building based on the architectural design. This means that cadastre cannot directly use BIM/IFC designs to register a building. Therefore, a spatial unit can be associated only with LADM's survey type of *LA_SpatialSource*. This process is done in accordance with the Ordinance of geodetic reports (Official Gazette 2018a). Currently, for each building the following attributes are registered in the cadastre: area, intended building use, building name, and the address.

Additional information (attributes) should be recorded in the Building Register, such as: footprint of the building, 3D building model, altitude of the building, height of building. Table 1 proposes the basic attributes necessary for efficient land administration.

The class *HR3D_LegalSpaceBuildingUnit*, which represents the building, is associated with cadastral parcel (*LA_SpatialUnit*). The class *HR3D_LegalSpaceBuildingUnit* is a descendant of the class *LA_SpatialUnit* and inherits the association *suHierarchy*, which allows modelling association between building parts and building (Fig. 5). Also, this allows modelling different RRRs for the complete building and for its parts (shared or individual parts) For instance, large buildings can be divided into several parts that even are visually different. Each building part can then have individual building number. In INSPIRE data specification on buildings (INSPIRE 2013) this is modelled explicitly with two classes

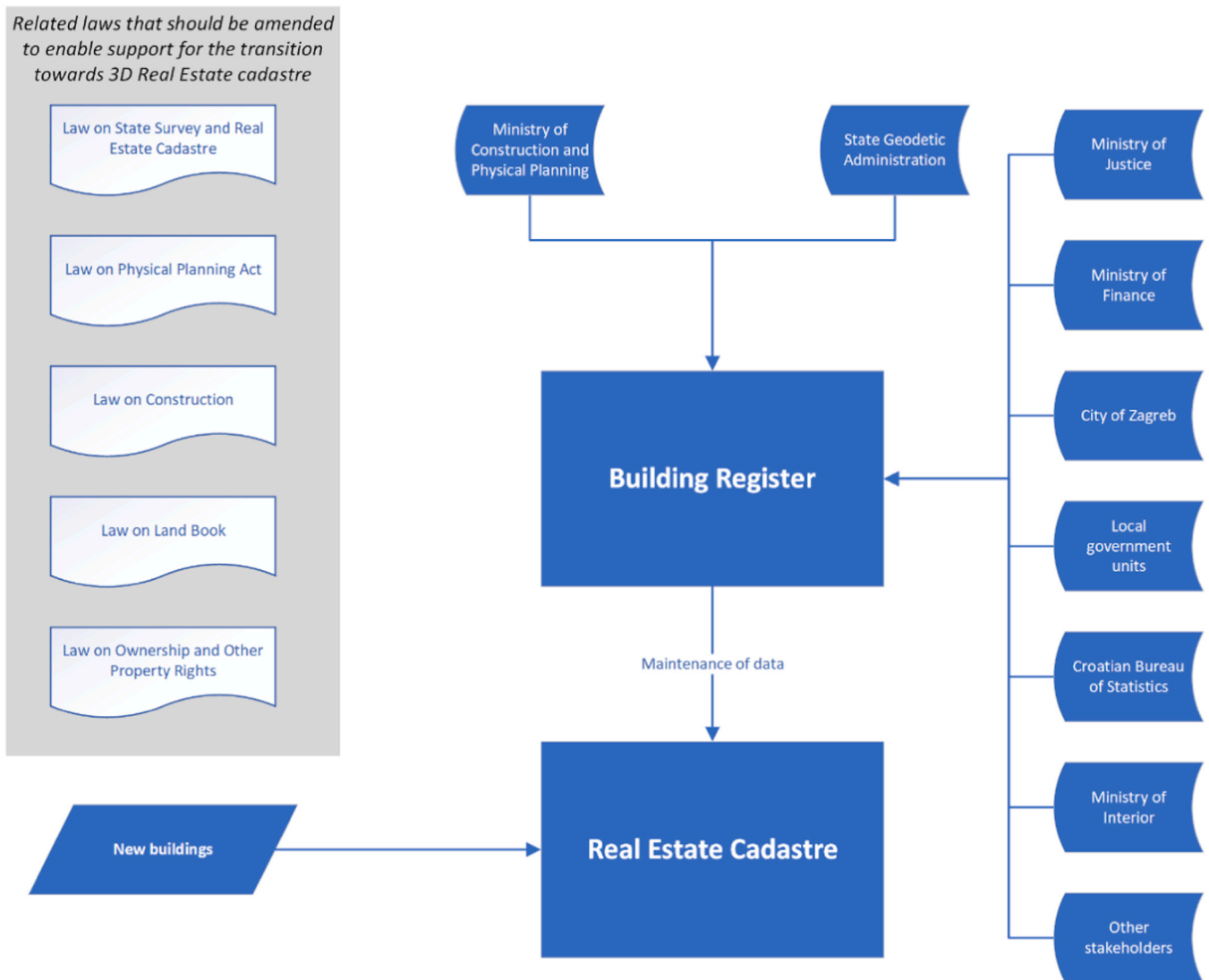


Fig. 4. Establishing the building register (the source data and related laws).

Building and *Building part*, both descendants of the class *AbstractBuilding*. For each unit of use of a building, the following attributes should be collected:

- o unique identifier,
- o land book owner,
- o real use of the building unit,
- o area,
- o method of determining area,
- o rooms.

Based on the previously listed attributes and associations the following conceptual model for the Building Register has been proposed. The model is similar to the model developed by (Vučić et al., 2020). However, the data stored within the Building Register might be very different than the data that should be stored in 3D cadastre. Since the Building Register should collect heterogeneous datasets about buildings from different registers, the completeness and the quality of the data might not be satisfactory. Therefore, the main idea of the Building Register is to gradually improve the data about the buildings and migrate them as they are improved to the 3D cadastre.

The attributes of buildings and condominium units are defined based on the analysis of current legislation, currently available data about the

buildings and the needs for managing the data about buildings and their parts. Room class and renovation class (a list of interventions on the building, ranging from simple interventions such as painting to more complex ones such as static reconstruction to increase the earthquake resilience), were added in the process of developing the Building Register. Stakeholders expressed interest in that data and in the process of creating a LADM compatible 3D cadastral database.

4.2. Unique identifiers of unit of use of buildings – a case study in Croatia

There are several methodologies to assign unique identifiers to units of use of a building. The simplest is to set up a simple counter, which would assign a new identifier to each new unit of use of the building. However, even though we live in a digital world there may not be the need to be bothered with identifiers, it might be useful to have intuitive identifiers defined in a logical order which would make easier for people to find certain apartments or office spaces. This could be the most convenient option for the public, while at the same time not ambiguous. This might be especially useful for large buildings. Today, almost any address can be found in a simple manner by using a smartphone, but once one enters a building it may become harder to find the desired location. Because of that, it is proposed to generate a unique identifier for each unit of use of buildings by including information about the floor

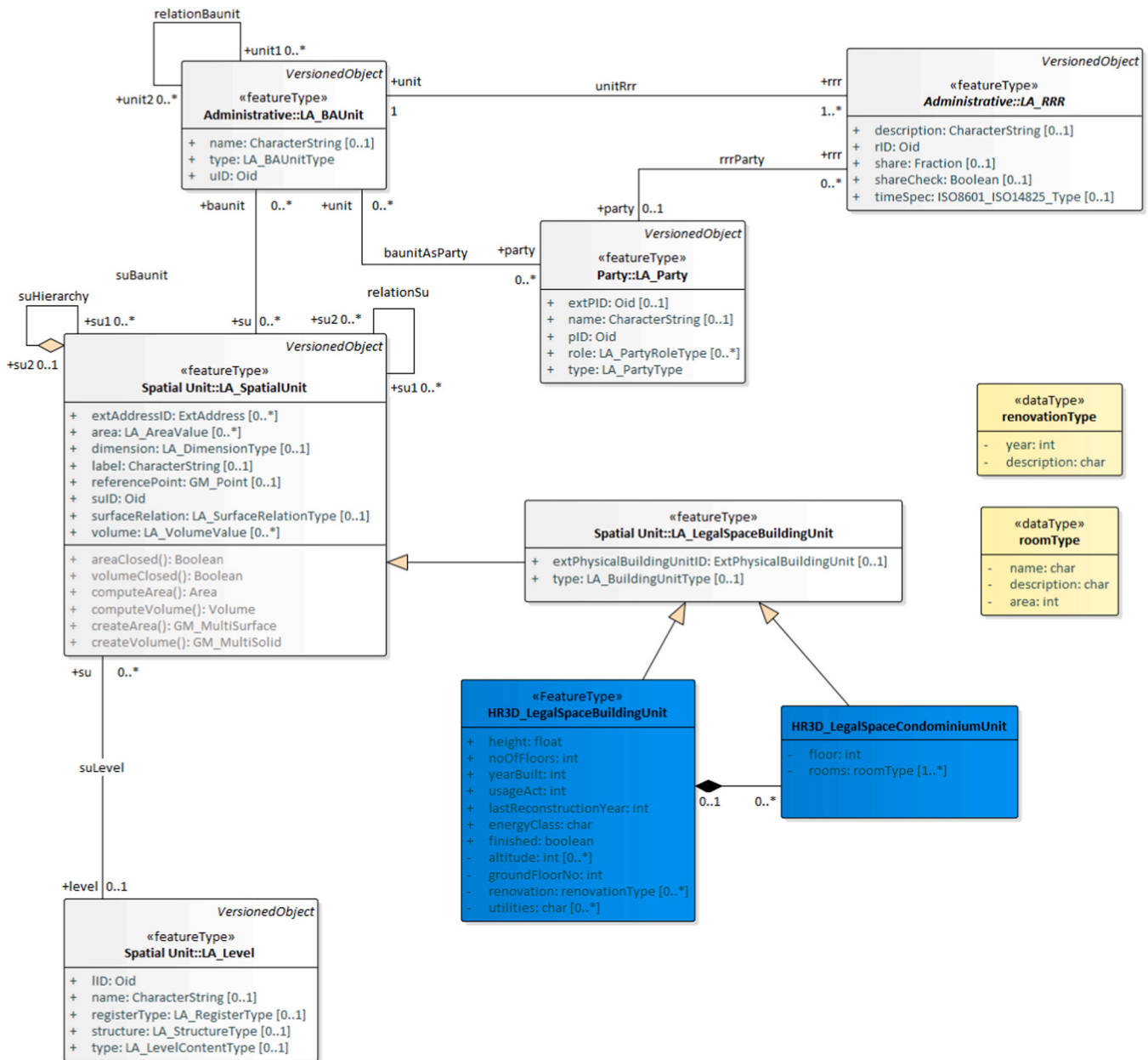


Fig. 5. Conceptual model of the Building Register.

and number of that part on the floor. These identifiers can be assigned in a logical spatial order. Additionally, in the identifier it is proposed to include the cadastral municipality identifier, and the ordinal number of a building within the cadastral municipality. The cadastral municipality identifier and building ordinal number are used instead of an address because the latter changes more frequently than cadastral municipalities. This is technically feasible and for citizens and other subjects (e.g. companies) it is more practical to find certain unit of use of the building. In cases of apartments that span over multiple floors, an identifier is assigned to the floor where the entrance closer to the ground floor is located. Thus, the unambiguous recognition of a cadastral municipality in the Croatian LAS is defined by the registration number and name of the cadastral municipality (e.g. Cadastral municipality 335240 Centar, which unambiguously defines this cadastral municipality by unique identifier and by name).

In the Croatian land administration system, the cadastral municipality and the cadastral area at sea are spatial units for which cadastral evidence is prepared. The cadastral municipality, as a rule, includes the

area of one inhabited place with the corresponding land, the area of one settlement (Official Gazette 2018). A cadastral municipality may include several settlements, i.e., one settlement may be divided into several cadastral municipalities if there are justified reasons for that (small or large settlements).

Previously, unique real property identifiers have been generated from the registration number of the cadastral municipality, the number of the land book entry and the number of the land book sub-entry. However, this is obsolete since after many years in the Republic of Croatia's land book has been improved in terms of recording unit of use of real property (apartments and office spaces) and it is still a better solution to create unique identifiers of unit of use of buildings using cadastral data since they are since they are more complete and in better condition than the land book data. Rules on linking the land book and the register of deposited contracts and registration of ownership of the unit of use of the real property have improved the process of registration of unit of use of buildings (Official Gazette 2010). One of the additional reasons for proposing a new methodology of a unique identifier is the

Table 1
Data about buildings.

Attribute	Description	Mandatory	Data type
building identifier			
cadastral municipality identifier		YES	code list of cadastral municipalities
the number of the building within the cadastral municipality		YES	Integer
cadastral parcel identifier		YES	String
footprint of the building	maximum outline of the building or building point, outline as seen from above in ortho photo, including roofs wider than the building walls	YES	Polygon
3D geometry	3D geometry representing the building	NO	Geometry
land area under the building	land area under the building recorded in the Land Cadastre or obtained in some other way (measurement, calculation from the building footprint, ...)	NO	Integer
address of the building	address structured from the Register of administrative units	NO	String. (defined in the Register of administrative units)
altitude of the building (minimum, terrain, maximum)	altitude of the building: - minimum (altitude of the lowest point of the building) - terrain (altitude of the terrain adjacent to the building) - maximum (altitude of the highest point of the building)	NO	Integer
height of the building	height difference between the lowest and highest point of the building	NO	Integer
number of floors		YES	Integer
year of construction		YES	Integer
Building/use permit	the data are already included in the Joint Information System of Land Registry and Cadastre (JIS)	NO	Uniform resource identifier (a link to the file)

fact that for approximately 250 cadastral municipalities in Croatia where surveys were made between 1950 and 2000 cadastral parcels are recorded in the cadastre, but not in the land book (consequently parcel numbers are different in cadastre and in the land book, but also the name of cadastral municipality can have different name in cadastre and in land book).

For this reason, the methodology for generating unique identifiers of unit of use of buildings is summarized. The unique identifier of a building's unit of use is a number consisting of the registration number (i.e. unique identifier) of the cadastral municipality, the ordinal number of the building within the cadastral municipality, the floor number and the ordinal number of the unit of use of the building on each floor. The ordinal number of a unit of use of a building on an individual floor can be determined by counting the unit of use of the building from left to right (clockwise) upon entering the first floor from the main staircase. Thus, an example of an apartment at the address Zagreb, Trnsko 12, for the first of a total of four apartments on the tenth floor would be as

defined in Table 2. It is assumed that this is the first building in the cadastral municipality Klara. The numbering of buildings within the cadastral municipality can be done randomly or better in some geometric order. Building numbers and numbers of unit of use are integers which can be formatted as in the example to form a fixed number of digits (with trailing zeroes). Fixed number of digits would make identifiers more uniform and easier to read especially if parts denoting different parts (building floor and building part). Another approach is land parcel number as starting point and add additional parts to identify the building units.

From a 3D model of the building made on the basis of project documentation or from the condominium report, each unit of use of the real property (apartment or office space as well as common spaces, e.g. balconies and staircases) can be drawn individually in three dimensions (Fig. 6). Also volumes can be calculated for the unit of use of the real property.

5. Practical examples

In this section several cases are used to demonstrate the benefits of the developed methodology for registering unit of use of buildings in the Building Register. Also presents practical examples of implementing the model as a means of evaluating the design. In the Republic of Croatia cadastral and land registry data are publicly available on the portal of the State Geodetic Administration and Ministry of Justice (URL 1). This portal provides, in addition to cadastral data, land registry data, geolocating services on a cadastral parcel or on a building by using GNSS sensor in devices such as smartphones or tablets. In addition to a geolocating service, the user can find data either by address or by cadastral parcel number (Fig. 7).

Thus, an example of a building (church) at the address Zagreb, Trg Sv. Marka 5 shown on Figure 6 is quite simple and can be easily found by using the address or cadastral parcel number. However, in order to make references to the building, Church of Saint Marko identifier should still be determined as shown in Table 3. It is assumed that this is thousandth building in the cadastral municipality Centar (unique identifier of cadastral municipality Centar is 335240).

It is again noted that numbering of buildings within the cadastral municipality can be done randomly or better in some geometric order since geometric order is used through history and it helped people to find parcels on the map in analogue form, but also in digital form

Another example of a residential building in the city of Vukovar includes multiple unit of use but it is quite simple building. Fig. 8 shows the outline of the building on State Geodetic Administration geoportal.

This case study shows a residential building with two building parts having the address Vukovar, Trg Žrtava fašizma number 3 and number 4, respectively. Next figure shows the actual photo of the building. This is a simple residential building of a rectangular form with a basement and three floors above ground (Fig. 9).

Unique identifiers of unit of use of this building in Vukovar city are represented in Table 4. It is assumed that building on house number 3 is the 30th building in cadastral municipality and building on house number 4 is the 31st building in cadastral municipality.

If each apartment would have unique identifier written above the door it would be quite simple to find an apartment within the building

Table 2
New proposal for determining the unique identifier of a unit of use of the property.

Number of the cadastral municipality	Ordinal number of the building in the cadastral municipality	Ordinal number of floor	Ordinal number of the unit of use of the property
335444	000001	+10	1
Unique unit of use of real property identifier			335444000001+10 1

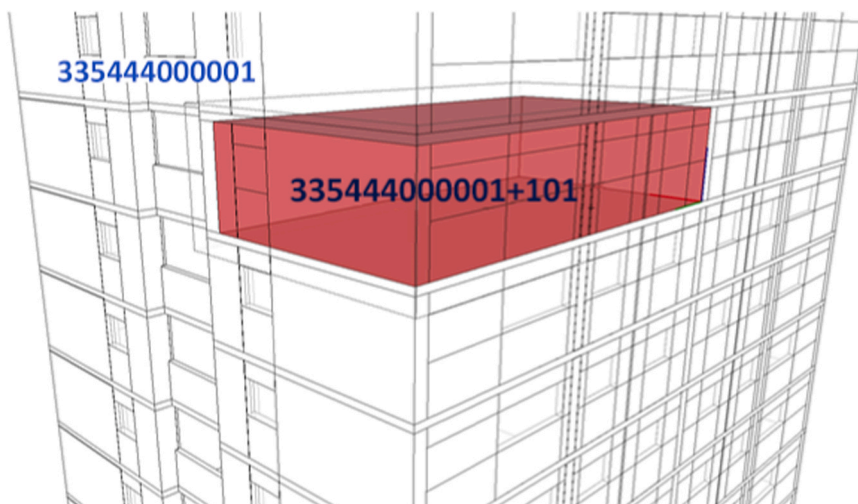


Fig 6. 3D model of building and apartment (Zagreb, Trnsko 12, tenth floor).



Fig. 7. Church in Zagreb, (address: St. Marko's Square 5), source (URL 1).

Table 3

New proposal for determining the unique identifier of building without unit of use.

Number of the cadastral municipality	Ordinal number of the building in the cadastral municipality	Ordinal number of floor	Ordinal number of the unit of use of the property
335240	001000		
Unique building number			33524 0001000

based on the unique identifier. For instance, for identifier 334316 000031+2 3 one could conclude it is the third apartment on the second floor. The described numbering of apartments can be used when making contracts to reference properties that are subject of buying or selling. Also, it would be easier to understand where the apartment is located

based on the identifier.

6. Discussion

As previously stated in this paper, the Republic of Croatia's land administration system is organized in a manner similar to some other countries, such as Slovenia, in that it comprises a dual registration system of cadastral and land registry parts. It was also stated that the processes of buying and selling real estate in Croatia and Slovenia are similar in some respects. However, each country faces unique technical and cultural-administrative hurdles in the development of each of their land administration systems. For example, Croatia experiences mismatches between the data in its cadastre and land registry, while in Slovenia this appears to be less of a problem. Also, Slovenia's rules on how 3D spatial units will be resolved is based on that country's local

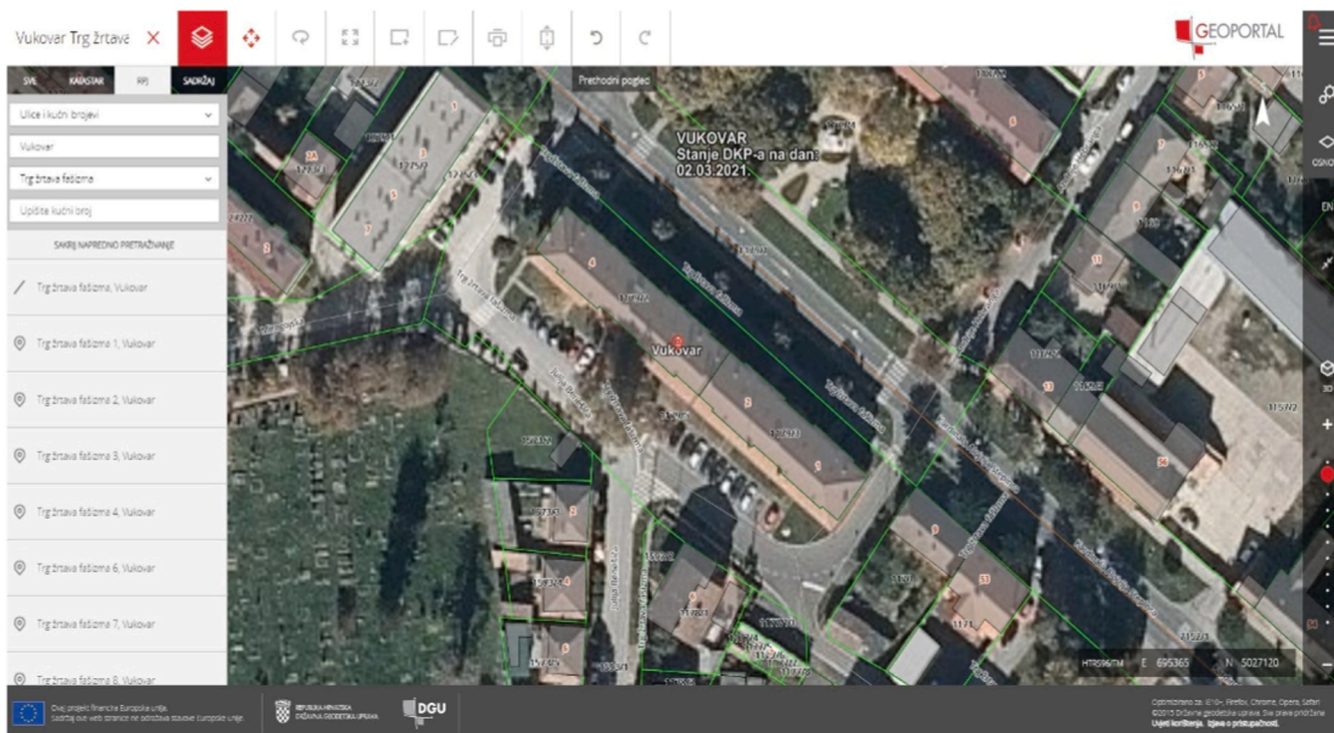


Fig. 8. Building in Vukovar city (address Trg žrtava fašizma 3, 4) on State Geodetic Administration Geoportal (2022)(source: URL 2).



Fig. 9. Building in Vukovar city (address Trg žrtava fašizma 3, 4), source URL 3.

technical and administrative situation, while Croatia will have to solve its problems based on its unique land administration related cultural and legal practices, as well as the technical status of its cadastre and land registry.

This paper deals with relatively simple but important issues faced by Croatia. The fact that Croatia does not have too many complex 3D situations means that the establishment of a full 3D cadastre is not an extremely demanding task, as it would be in more populated countries. A 3D cadastre is not necessary only for complex building situations. 3D cadastre can help in practice and everyday life wherever buildings with two or more apartments or office spaces exist. However, Croatia has a problem with registering unit of use of buildings, especially apartments

and office spaces. Currently, many units of use are registered in the Book of deposited contracts. The book of deposited contracts was intended as a transitional solution (from 1991 – 2013) until the final arrangement of the land registry status for the cadastral parcels on which the buildings containing the apartments or office spaces. The problem is gradually being solved by the rules on linking the land book and the register of deposited contracts and registration of ownership of the unit of use of real property. The name “Book of deposited contracts” suggests what is registered and no additional information is provided (no geometrical information or any other information). Some of the activities relevant to transferring such records into the land book where more complete information would be registered, are mentioned.

Table 4

Unique identifier of unit of use.

Cadastral municipality identifier	Ordinal number of building	Address Street / Square	House number	Ordinal number of a unit of use	Unit of use type	Floor	Unique identifier of unit of use of real property
334316	000030	Trg žrtava fašizma	3	1	apartment	0	334316 000030+0 1
334316	000030	Trg žrtava fašizma	3	2	apartment	0	334316 000030+0 2
334316	000030	Trg žrtava fašizma	3	1	apartment	1	334316 000030+1 1
334316	000030	Trg žrtava fašizma	3	2	apartment	1	334316 000030+1 2
334316	000030	Trg žrtava fašizma	3	3	apartment	1	334316 000030+1 3
334316	000030	Trg žrtava fašizma	3	1	apartment	2	334316 000030+2 1
334316	000030	Trg žrtava fašizma	3	2	apartment	2	334316 000030+2 2
334316	000030	Trg žrtava fašizma	3	3	apartment	2	334316 000030+2 3
334316	000031	Trg žrtava fašizma	4	1	apartment	0	334316 000031+0 1
334316	000031	Trg žrtava fašizma	4	2	apartment	0	334316 000031+0 2
334316	000031	Trg žrtava fašizma	4	1	apartment	1	334316 000031+1 1
334316	000031	Trg žrtava fašizma	4	2	apartment	1	334316 000031+1 2
334316	000031	Trg žrtava fašizma	4	3	apartment	1	334316 000031+1 3
334316	000031	Trg žrtava fašizma	4	1	apartment	2	334316 000031+2 1
334316	000031	Trg žrtava fašizma	4	2	apartment	2	334316 000031+2 2
334316	000031	Trg žrtava fašizma	4	3	apartment	2	334316 000031+2 3

Given that in the scientific and practical domain of geodesy and cadastre, 3D cadastre is a very interesting topic, and considering the fact that many countries around the world are trying to improve their land administration systems by implementing a 3D cadastre, it is clear from this research that the Republic of Croatia has a real need for 3D cadastre as well. The full implementation of Croatian 3D cadastre can certainly improve both the progress of the economy and a quality of life for citizens in other aspects that are not directly related to the economy (e.g. security of ownership, faster access to data, better internal navigation and the like). As with other countries mentioned in this paper (e.g. Serbia, Australia, Saudi Arabia, Malaysia), Croatia is also attempting to implement a 3D cadastre, but it is still closer to the scientific sphere of researching the possibilities of its 3D cadastre. One of the most obvious reasons is that the 2D cadastre was managed and developed for more than 200 years, and we can consider these initial years/decades of the 3D cadastre as a time for setting strong foundations for the future full implementation of a 3D cadastre.

7. Conclusions and future research

The main purpose of this paper was about explaining the refined information model, and conducting an initial assessment by testing the model with some use cases. Future work is about efficient workflow to realize the data collection for a large number of buildings. It is proposed that BIM/IFC be utilized in the development of the Building Register, especially because this approach is supported by recent relevant literature. In this paper the unique identifiers of unit of use of real properties based on cadastral data are discussed. The generation of unique identifiers in a logical and spatial manner, which would make them understandable to everyone is also proposed. If these identifiers would be posted on the entrance into the unit of use of buildings then this would make it easier for people to find apartments or office spaces based on the identifier, especially in large buildings.

One of recent activities is the project of implementation of the

Building Register in the Republic of Croatia, as a new part of the real property register. Such a register should serve as a transitional register towards the establishment of 3D cadastre. This register can be used as a platform for developing a better and more complete register, which would be fair basis for the taxation of properties but also for improving the management of real properties and resolving legal issues in multi-residential buildings. Croatia is one of the few European Union countries that do not impose a real property tax. One of the main reasons for this is the fact that the data stored in cadastre and land book is not reflecting the exact condition (as in on the field) in many cases. This is even more emphasized when 3D cadastre is taken into consideration. 3D cadastre can undoubtedly help to introduce a fair real property tax. Furthermore, it would be beneficial for better management of spatial and construction planning and housing policy, promoting the development of community and infrastructure planning, post delivery services, providing a better overview of apartments and office spaces. However, the fact that there is a large number of buildings still unregistered in the cadastre and land book, as well as the large number of apartment buildings where partitions into condominium units have not yet been conducted, pose the greatest challenges in establishing the complete Building Register.

One topic that has not been discussed in detail in this paper, but which may represent a significant step towards the implementation of a 3D cadastre, is the management of 3D Geometry/topology information in relation to building units.

The following options are recommended for future research:

1. For new buildings, local governments should request that architects provide 3D Building Information Models, (BIM) during the building construction phase, instead of the submission of 2D plans (as also should be done when requesting building permits) and, after construction, request an updated 3D BIM from the contractor;
2. For old buildings:

- 2a. Either convert floorplans to 3D models; or
 2b. Use 3D laser scanning with machine learning for automated creation of 3D UnitId.

Future research can include following topics:

- Conduct comparative study with other countries registering 3D apartment rights
- Try developing an internationally agreed harmonized model based on common elements and best practices (and develop a country profile for Croatia).
- Integrate registration of 3D apartment rights with other aspects of land administration (survey, 2D land parcels, spatial plans/permitting, valuation/taxation)

It is to be noted that there are some benefits in a random approach proposal for unified identifiers in the domain of dissemination and managing spatial data. The Croatian Land Administration tools (Joint Information System of Land Books and Cadastre, Geoportals etc.) currently align with our proposal in reality.

Our proposal for unified identifiers for units of use is also user friendly for stakeholders of Land Administration in Croatia. It is better for indoor navigation of buildings because it is similar to other current systems with which people are already familiar. Also, having such identifier would make it easier to reference apartments in a contract that now is required to contain a complete description of the apartment which can sometimes be unclear. The proposal also represents a unique scientific interim contribution to the development of a 3D cadastre in Croatia as it sets the basis for further developments.

CRediT authorship contribution statement

Saša Vranić: Writing – review & editing, Writing – original draft, Supervision, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Michael Sutherland:** Writing – review & editing, Supervision, Methodology, Investigation, Formal analysis. **Peter van Oosterom:** Writing – review & editing, Supervision, Methodology, Investigation, Funding acquisition, Formal analysis, Conceptualization. **Nikola Vučić:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data is public available on public Land Administration web portals. References is in the paper.

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