Building Register – Basis for 3D Cadastre

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Key words: building register, 3D cadastre, land registry

SUMMARY

Cadastral systems need to be designed and supported from three-dimensional spatial perspectives.

To create the 3D cadastre, a building register is needed. Development of the building cadastre can be based on the records of state surveys, spatial units registers, land registers, records of local and regional self-government units, data from construction files according to special regulations in the field of spatial planning, records kept by building managers, and other sources.

The most significant element of the 3D cadastre is comprised of buildings and separate parts of buildings, followed by public utility infrastructure and complex spatial real-life situations (bridges, tunnels, overpasses, underpasses, overlapping of constructed objects with natural facilities, large shopping malls with more underground and overhead floors etc.).

This paper investigates important steps in establishing the building register. We propose how to upgrade the building register into the 3D cadastre, based on examples from Croatian land administration system. The most significant use cases in 3D cadastre are shown in this paper as well.

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1. INTRODUCTION

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. Under 3D cadastre, the 2D cadastre management of data cannot meet the real land management of the three dimension space aspect and property. It is essential to introduce the 3D cadastre (Choon and Seng, 2013).

The limited advances in full 3D cadastre implementations throughout the world might be explained by the fact that the implementation of the 3D cadastre requires close collaboration between legal and technical experts in an empirical environment to understand the impact of each other's domain (Stoter et al. 2012).

In the Republic of Croatia (and other countries where cadastre was established a long time ago), many registers and official databases on land and interests were created where certain overlaps between some segments are evident. These were most often established independently and therefore contain a lot of redundant data. However, their interaction can be used to gain new values and establish Multipurpose Land Administration Systems (Vučić et al., 2017).

A 3D object in the 3D cadastre is defined as such a geometry that has vertical faces enclosing a 3D space with roofs and floors. A 2D object (parcel in the current cadastral system) is a special case of a 3D object which has the coincident roof and floor, and collapses into a polygon. A 3D object termed ‘3D property’ refers to a spatial envelope containing the construction built with the land space, rather than a space of land rights because the current laws and regulations cannot give a clear and explicit statement about the spatial extent of the rights and it is impossible to describe the spatial extent of those rights (Guo et al 2011).

Cities are increasingly adopting 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. 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 neighbourhood, and predicting how much solar irradiation the roof of a building receives in order to assess whether it is economically feasible to install a solar panel (Biljecki 2017).

In the Republic of Croatia, the new State Survey and Real Property Cadastre Act stipulates the establishment of a new register called the "Building Register”.

This paper is organized as follows. Section 1 is introduction. Section 2 analyses Croatian LADM profile. Section 3 describes process of registering buildings in the Croatian land administration system. Section 4 describes elements for establishing the Building register and quality control of 3D cadastre data. Section 5 describes spatial data quality in 3D cadastre. The paper ends with conclusion.

2. CROATIAN LADM PROFILE

The first version of the Croatian LADM profile was developed in 2012. New classes, attributes, and types were added in the code list. For the attributes added in classes HR_SpatialUnit: HR_UsageTypeLand and HR_UsageTypeBuilding (Figure 1), the corresponding code list was created according to the Regulation on Land Cadastre and according to the Regulation on the Content and Form of Real Property Cadastre Documentation (Figure 2). The code list was also created for HR_OwnerType, HR_MonumentMaterial, HR_BoundaryType attributes, in accordance with the current State Survey and Real Property Cadastre Act.

Another important contribution to the development of the 3D Cadastre in the Republic of Croatia is the introduction of the unique identifier of special parts of real property, proposed to be implemented in the State Survey and Real Property Cadastre Act and the Land Registration Act (Vučić 2015).

The unique identifier of special parts of real property is a solution for all objects that are needed for the development of 3D Cadastre (buildings of various purposes, underpasses, overpasses, tunnels, bridges, viaducts, underground buildings, etc.).

The unique identifier could be used for denotation of separate parts of buildings, such as flat, apartment, business space, where each separate part gets a unique identifier in the Croatian land management system.

The unique identifier of a special part includes:

- identification number of the cadastral municipality
- number of land registry file
- number of land registry sub-file.

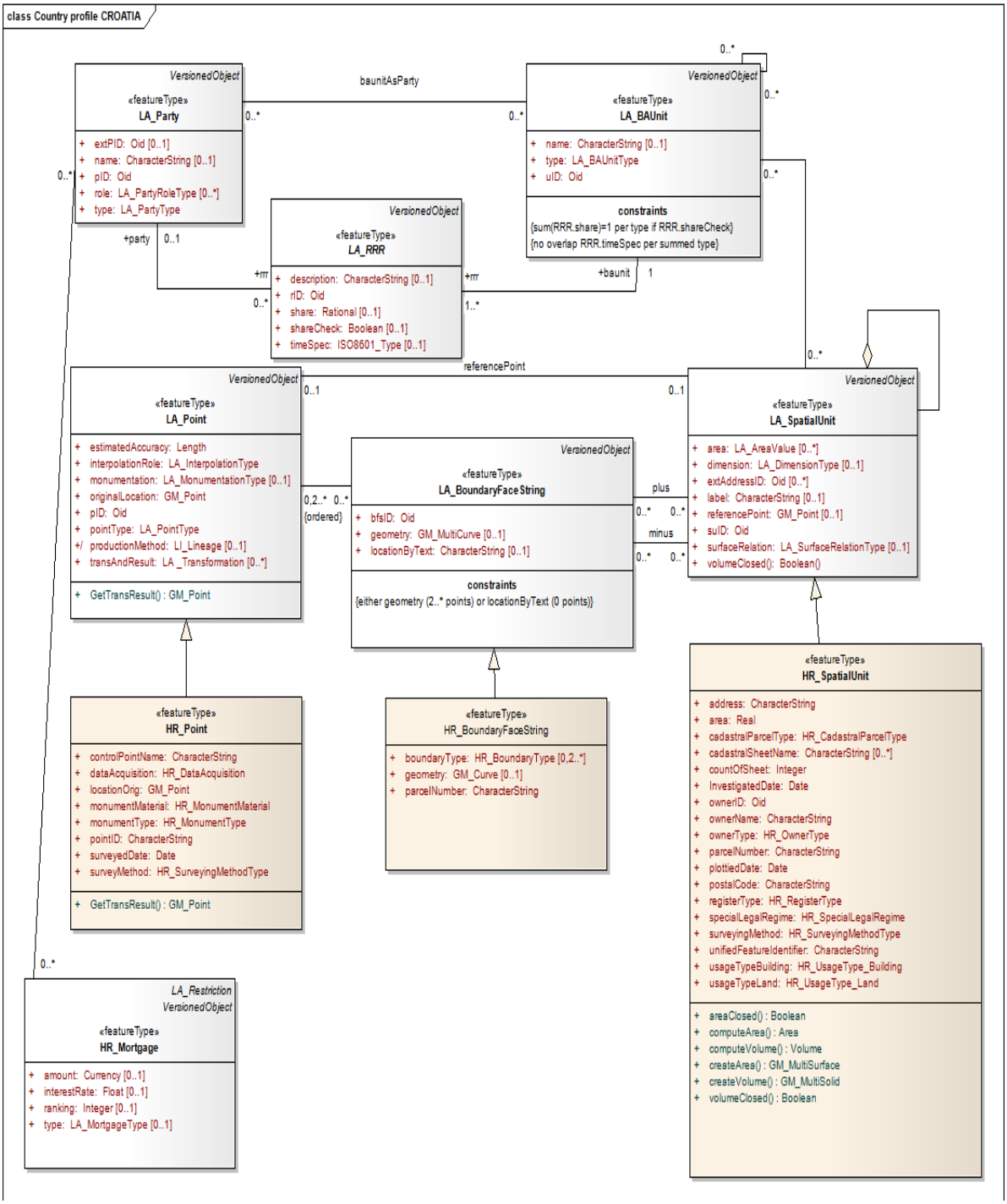

Figure 1. LADM profile for the Republic of Croatia

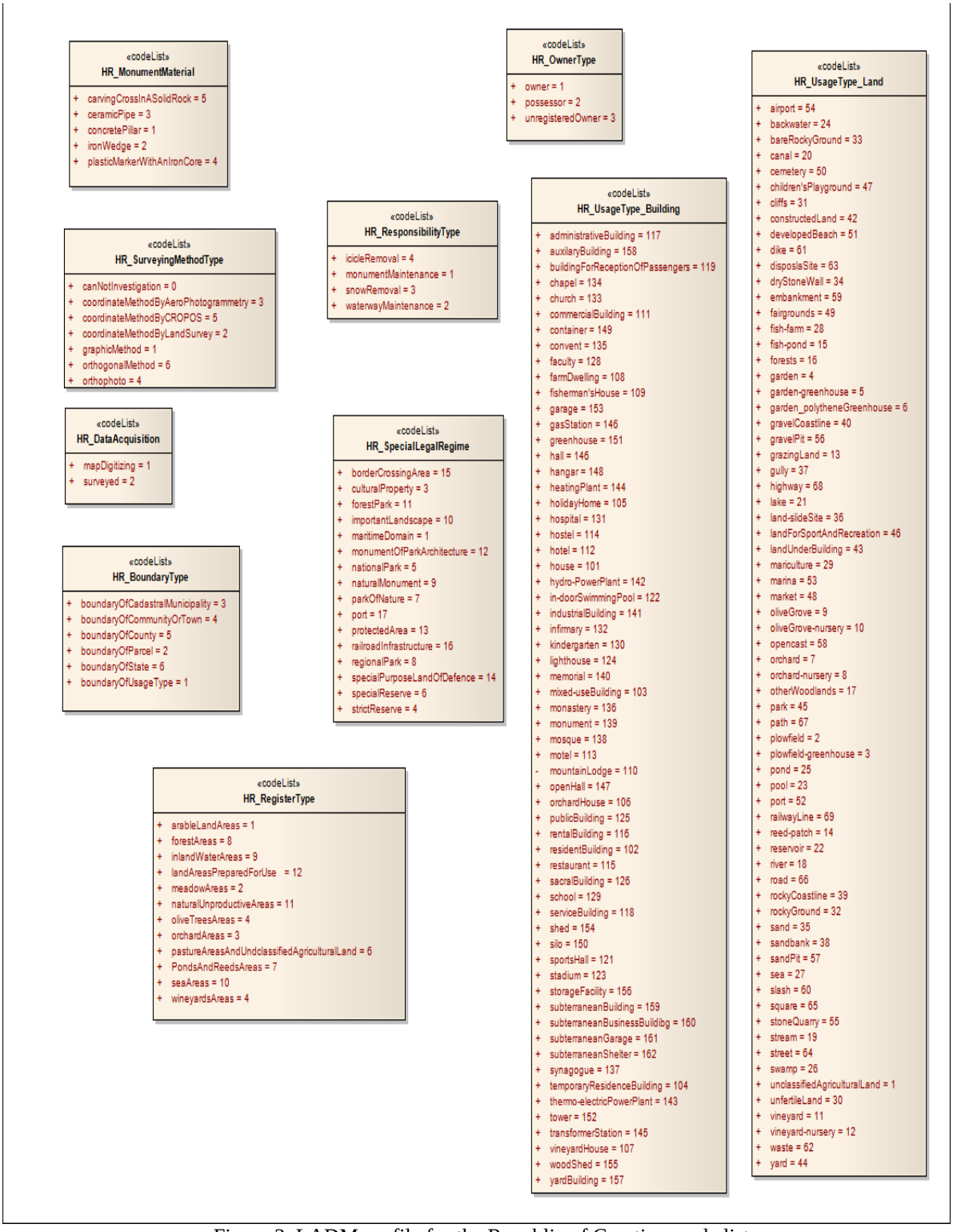

Figure 2. LADM profile for the Republic of Croatia – code lists

3. REGISTERING BUILDINGS IN THE CROATIAN LAND ADMINISTRATION SYSTEM

Data about buildings are entered into land books based on information delivered to the land registry by the cadastral office. Ownership of a particular part of real property (e.g. an apartment or office space) is realized through registration in the land registry. Such separate parts may be registered if they constitute independent units of use. Separate parts may include balconies, terraces, basements, and attics, under the condition that they serve exclusively a single particular part and are clearly separated from other parts of the real property. Land book registration of particular parts of real property is not possible without a partition of real property. The same procedure is commonly used in the land registry to formally consolidate land which was often publicly owned with buildings constructed on that land. Partition of real property serves to establish ownership of particulars part of real property (apartment, office space, garage, etc.) that become associated with the proportionally shared part of real property (Vučić et al. 2013).

Fair relationship in financing the maintenance of buildings is furthermore made possible by establishing ratios of each party's ownership in the real property and, hence, each party's proportional share in the shared ownership of common parts.

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

4. ELEMENTS FOR ESTABLISHING THE BUILDING REGISTER

The standard attempts to assign standardized classes to generally differentiate grades of 3D data. The geometric detail and the semantic complexity increase with each level (Figure 3). This LOD categorisation is well known in the 3D GIS community (Biljecki 2017).

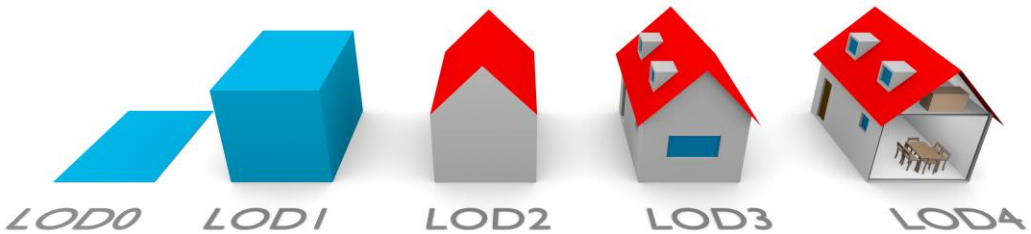

Figure 3. The five LODs of the OGC CityGML 2.0. (Biljecki 2017)

The attributes of the objects are:

- **building** (identification code of the building, identification code of the cadastral parcel, address of the building, footprint of the building, 3D building model, parameters of positional and height accuracy, real use of the building, land area under the building, altitude of the building (minimum, terrain, maximum), height of the building, number of floors, number of the ground floor, number of apartments/business premises in the building, building permit, level of construction, condition of property, year of construction, year of facade renovation, year of roof renovation, electricity, sewerage, water supply, gas, energy certificate, type of investors, type of foundation, material of bearing structures)
- **floor** (identification code, footprint of the floor, type of floor (underground/above ground), number of the floor, altitude of the floor, height of the floor)
- **roof** (footprint of the roof, ridge of the roof)
- **building unit** (identification code, address, land registry file, owner, real use of the building unit, area, method of determining area, building manager, number of rooms, bathroom, toilet, kitchen, year of the renovation of installations, energy certificate)
- **part of the building unit** (identification code, footprint of the part of the building unit, 3D model, parameters of positional and height accuracy, real use of the part of the building unit, area, energy certificate, type of heating)
- **rooms** (real use, area)

4.1 Data about buildings

Buildings are registered in the cadastre on obligatory request of a party. A geodetic report prepared by an authorized surveying company must be supplied with this request. The responsible cadastral office must review and confirm the report. Surveying companies have at their disposal many surveying methods, including the modern GNSS surveying method, while field surveying must be performed with minimally the same accuracy as cadastral surveying or technical supervision used for preparing the cadastral record for the cadastral municipality where the relevant building stands. Buildings are registered in the cadastre with the following attributes: area, intended building use, building name, and house number.

Additional information (attributes) needs to 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.

Table 1. Data about building

Attribute	Description	Obligation	Code list
identification code of the building:			
• code of cadastral municipality		YES	code list of cadastral municipality
• the number of the building within the cadastral municipality		YES	numerical value from 1 to n
identification code of the cadastral parcel		YES	defined in the Land Cadastre
footprint of the building	maximum outline of the building or building point	YES	polygon or point
3D building model	building volume	NO	building volume
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	numerical value from 1 to n
real use of the building	code from the National Classification of types of construction	YES	code list
address of the building	address structured from the Spatial Units Register	NO	defined in the Spatial Units Register
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	numerical value between -200 and 2500
height of the building	height difference between the lowest and highest point of the building	NO	numerical value between 0 and 1000
number of floors		YES	numerical value from 1 to 100
number of the ground floor		YES	numerical value from 1 to 100
year of construction		YES	year between N and today's date
building permit	the data are already included in the Joint Information System of Land Registry and Cadastre (JIS)	NO	alphanumeric value

The object Building is linked to the Land Cadastre (particle or a building that already exists in the JIS), topography, address, building part, building unit, floor and roof.

Features of the building:

- building is associated with one or more cadastral parcels,
- building is associated with one or more buildings in the topography,

- each building has a minimum of one floor,
- each building has at least one building part,
- each building has at least one building unit,
- each building can have one or more addresses.

4.2 Collecting information on buildings

To complement those already registered in the cadastre and land registry, information can also be collected by aerial imaging (stereo restitution) or LIDAR scanning.

With stereo restitution, the height of the surface near the building is collected, the highest point of the building, the main ridge of the roof, and the height and layout of the outer edge of the roof. Based on these data, a simple 3D model consisting of the building with a roof can be created and on the basis of measured heights, the height of the building can be calculated.

Collecting the building layout data and its height is also automatically recorded by characteristic contours of the building using LIDAR data. Use of the automatic classification of LIDAR data is the easiest way to create point clouds of buildings. With software applications, characteristic contours of the buildings can be created, which can be used for the establishment of the initial building register.

4.3 Proposed separate parts to be entered in the building register

Along with the attributes entered in cadastral records for over two centuries, new, additional attributes need to be collected for establishing the cadastre of buildings, as detailed in Table 2.

Table 2. Data about separate parts of real property

Attribute	Description	Obligation	Code list
identification code of the building:			
• code of cadastral municipality		YES	code list of cadastral municipality
• the number of the building within the cadastral municipality		YES	numerical value from 1 to n
identification code of the cadastral parcel		YES	defined in the Land Cadastre
footprint of the building	maximum outline of the building or building point	YES	polygon or point in RoC
3D building model	building volume	NO	building volume in RoC
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	numerical value from 1 to n

real use of the building	code from the National Classification of types of construction	YES	code list
address of the building	address structured from the Spatial Units Register	NO	defined in the Spatial Units Register
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	numerical value between -200 and 2500
height of the building	height difference between the lowest and highest point of the building	NO	numerical value between 0 and 1000
number of floors		YES	numerical value from 1 to 100
number of the ground floor		YES	numerical value from 1 to 100
year of construction		YES	year between N and today's date
building permit	the data are already included in the JIS for object BUILDING:	NO	alphanumeric value
year of the facade renovation		NO	year between N and today's date
year of the roof renovation		NO	year between N and today's date
electricity	the existence of electrical networks	YES	code list
sewerage	the existence of sewerage system	YES	code list
water supply	the existence of water system	YES	code list
gas	the existence of the gas infrastructure	YES	code list
identification number of the energy certificate	data are taken from the records of the Ministry of Construction and Physical Planning	NO	take the code list of the identification number of the energy certificate
energy certificate (document)	data are taken from the records of the Ministry of Construction and Physical Planning	NO	the scans
the level of construction	the level of construction of the building	NO	code list
type of investors		NO	code list
condition of property	maintained / neglected / .. or other criteria that will determine the Tax administration? (How will it determine should prescribe the Ministry of Construction and Urban Planning)	NO	code list

number of apartments in the building	derived data	NO	numerical value from 1 do 1000
number of business premises in the building	derived data	NO	numerical value from 1 do 1000

Shared owners of real property remain herewith in a shared ownership over the common parts, while each person becomes an individual owner of separate parts (e.g. apartment or office space). The method of registering elaborates on condominium partition of real property (Figure 4) was introduced in 1996. There are many real properties in Croatia which have not yet been registered according to that method.

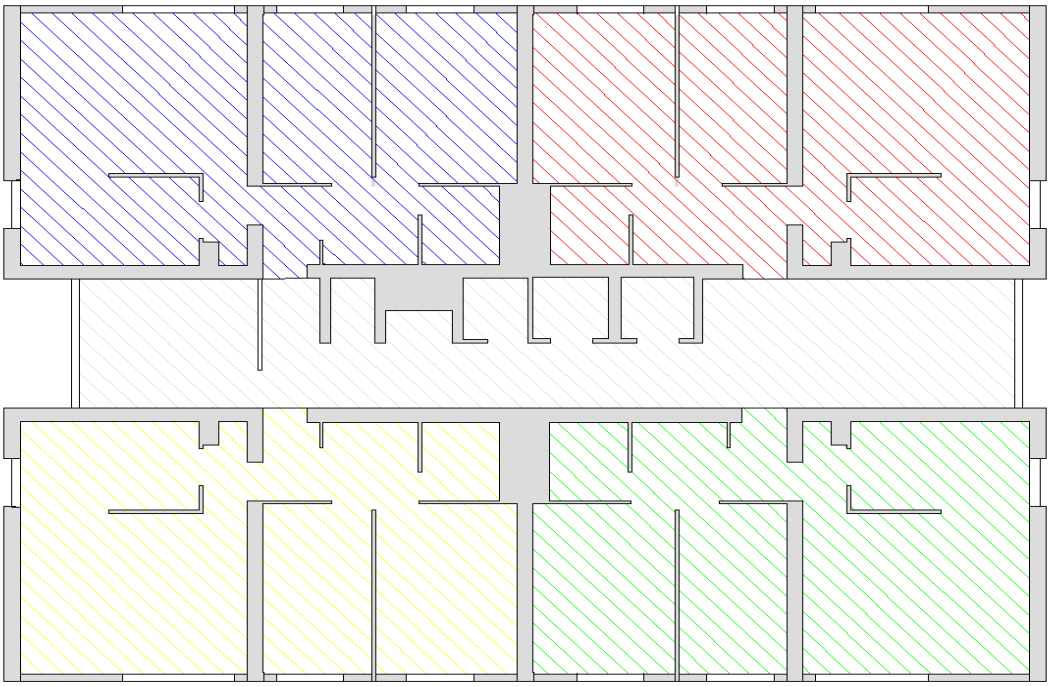

Figure 4. Part of an elaborate on condominium partition of real property (first floor)

Models have been made from the 2D building plans that are used for elaborate on partition of real property (Figure 5). In that elaborate there is an original 2D measurement data of every floor and by heights we can also easy calculate a volume of every separate part of property.

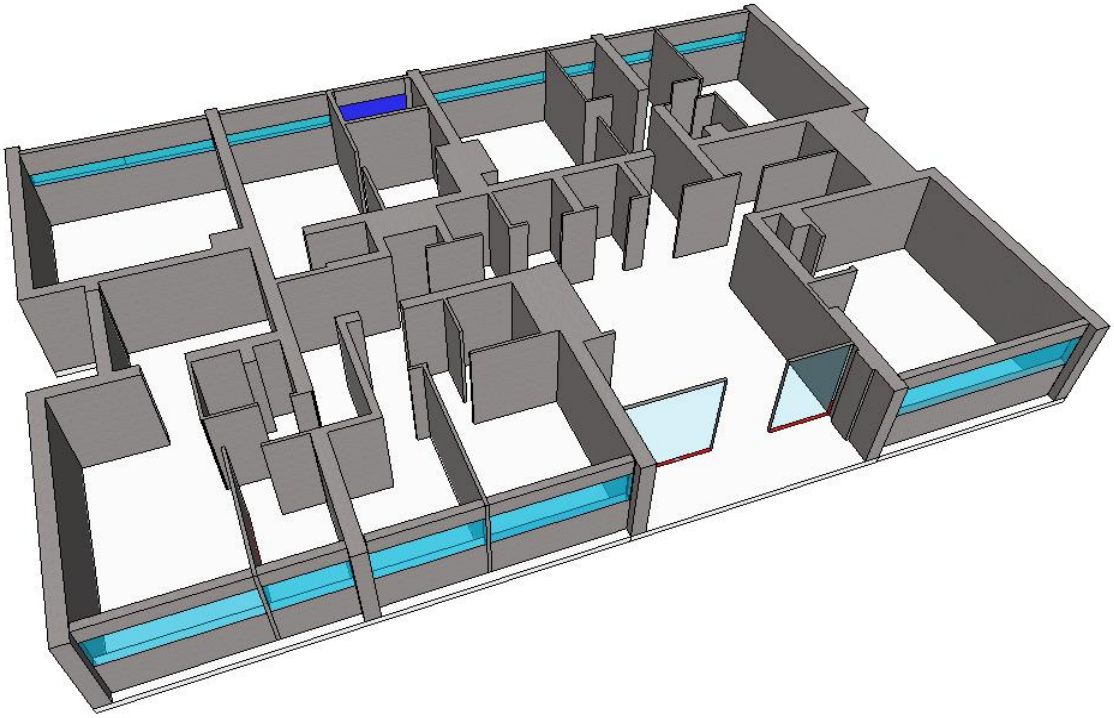

Figure 5. Residential building (3D model of a floor)

Today's computer technology provides advanced methods of registration in official registers. For the purpose of implementing a building register the 3D models can be used (Figure 6). This model can be linked to the Unified Feature Identifier of particular part of real property or to the number of cadastral parcel in the database and also integrated (by coordinates) with matching 3D cartographic view developed within the national land administration system (Vučić et al. 2013).

Figure 6. Residential building (3D model)

5. SPATIAL DATA QUALITY IN 3D CADASTRE

In 2009 Karki et al. investigate about data validation in 3D cadastre. Validation is initially approached to answer questions such as: "*what is validation? why it is necessary to validate?, and how do we validate?*". Limiting the scope to the 3D geometry or spatial representation of a 3D cadastre, their paper takes a novel approach in identifying the various aspects of validation of a 3D cadastral parcel and identifies the critical validation factors (Karki et al. 2009).
For the area of Republic of Croatia in 2019 Moharić et al. present an overview of some of the most important on-going activities in the cadastral system of the Republic of Croatia in this respect, as well as the historical cross-section of a unified digital cadastral database establishment activities and the transition towards digital cadastre (Moharić et al. 2019).
Step towards 3D cadastre also requires the processing of data inside a building on all apartments and office spaces within a single building. There are not many complex real-life 3D situations in the Republic of Croatia (such as tunnels, bridges, complex underground buildings, overlapping bulidings etc.), and the formation of a 3D cadastre is mostly reduced to the registration of the third dimension as well as to the registration of special parts of buildings.
Spatial data quality in the 3D cadastre is based on the appropriate processing of 3D data, respectively in the alignment of the graphic data of the floor plans of special parts of buildings with the written data on the surfaces of special parts. It is possible to introduce the volume of special parts of a building as a collected or calculated data. In order to control the quality of the data it is necessary to perform additional field measurement with affordable handheld laser distance meter. To achieve higher level of accuracy quality control can be integrated on the application level, e.g. applications responsible for cadastre management and maintenance.

6. CONCLUSION

Implementation of the Building Register project in the Republic of Croatia, as a new part of the real property register, is essential for the establishment unique register of buildings. This register will served as a platform for developing a good, complete and fair basis on which property tax can be established, for improving management of real property and resolving legal issues in multi-residential buildings, for better management of spatial and construction planning and housing policy, promoting the development of community and infrastructure planning, providing a better overview of apartments and office spaces, allowing better application, as well as providing a systematic statistical list. The biggest problem in establishing the building register is the large number of buildings unregistered in the cadastre and land registry, as well as the large number of apartment buildings where a partition into condominium units has not been conducted. The project of establishing the building register should, among other things, resolve this problem.

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