Developing Serbian 3D Cadastre System - Challenges and Directions

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SUMMARY

The real estate cadastre in the Republic of Serbia is based on 2D cadastral maps and procedures that do not support unequivocal registration and visualization of complex 3D property situations or complex objects located on/below several parcels, especially in urban areas. Within this study, we analyzed and documented specific situations concerning registration challenges for the current cadastral system in the Republic of Serbia. Furthermore, the analysis of additional functionalities which will enable overcoming the limitations of the current cadastre in the short to the medium-term time period is represented. The main objective is to use the current cadastral data and procedures as far as possible in order to keep the transition smoother and economically feasible. Having in mind this objective, the variation of the hybrid approach as the solution for Serbian 3D real estate cadastre was analyzed. One of the preliminary assumptions of this research is that it is possible to develop a system that is simple enough for implementation and maintenance, but at the same comprehensive enough to overcome the difficulties of the current real estate cadastre. Within the case study, 3D objects based on data currently provided by licensed surveying agencies are presented.

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1. INTRODUCTION

In the Republic of Serbia, there are two basic registration systems, the real estate cadastre, and the utility cadastre. The real estate cadastre is the basic public register of real estate and real rights on them, while the utility cadastre is the basic register of utility lines and real rights on them (Official Gazette, 2009).

The real estate cadastre in the Republic of Serbia contains two sets of data, i.e., cadastral maps (or digital cadastral map) and real estate cadastre database (in further text cadastre database). The cadastral maps contain geometry and topology data on real estate and provide spatial visualization of the real estate with 2D cadastral parcel as the basic spatial unit. In the cadastre database, other data on real estate are also stored. Such a system has a series of difficulties to unambiguously register and visualize complex 3D situations (see section 2) which are very common in densely populated urban areas.

As noted in the study (Dimopoulou et al, 2016), for the purpose of minimizing the necessary financial and human resources, low cost and use of existing data sources in the development and implementation of the 3D cadastre can be encouraged in developing countries. A similar statement can be found in the study (Griffith-Charles and Sutherland, 2013) where the authors say that lower-income countries should pay attention to a cost-benefit analysis when establishing 3D cadastre. A number of other studies use or propose extensions of the current national cadastral systems to support 3D registration as a most feasible solution (Stoter and Salzmann, 2003; Kitsakis and Dimopoulou, 2014; Gulliver et al, 2017; Stoter et al, 2017; Jaljolie et al, 2018). Countries with a similar cadastral background as Serbia (former Yugoslavian republics) are on the same track. Authors from Slovenia (Drobež et al, 2017) claims that the necessary data for establishing the third dimension could be gathered in the current cadastral procedures. Similar claims are also provided for Croatia case (Vučić et al, 2017).

On the other hand, it can be assumed that full 3D cadastre would meet all the needs of the Serbian 3D cadastre. Some studies show that full 3D cadastre will not be implemented in the short to medium-term future (Stoter and Salzmann, 2003; Stoter et al, 2017) and that it is better to focus on a feasible solution in the nearby future. This is in line with the results of the 3D Cadastre questionnaire where most of the countries did not predict significant progress towards the 3D cadastre in the near future (van Oosterom et al, 2014). The adopted strategy (Official Gazette, 2017) for the reform of the Republic Geodetic Authority in Serbia until 2020 does not include planned road toward full 3D cadastre. This could mean that transition stages are needed before establishing a full and precise 3D cadastre. The first stage would be upgrading the current cadastral procedures and data to meet the concept of hybrid 3D cadastre.

In this context, the main goal of this paper is to propose additional functionalities, based on the analysis of international experiences and the needs of the real estate cadastre in the Republic of Serbia. These functionalities should facilitate overcoming difficulties of the current real estate cadastre (when it comes to registration of 3D situations) and represent the base for the road towards the full 3D real estate cadastre. Also, the objective is to use the current cadastral data and procedures as much as possible to ensure an easier and economically feasible transition. In other words, we propose a minimal set of functionalities that will initiate transition of the Serbian cadastre towards a full 3D real estate cadastre and which is possible to implement in the short to medium-term future.

3D cadastre solution depends on the particular jurisdictions and requirements and it is driven by user needs and technical possibilities (van Oosterom, 2013). Therefore, this work is based on an extensive study of cadastre laws and regulations in Serbia and the proposals that were published on 3D Cadastre workshops, scientific papers, questionnaires on 3D cadastre in different countries (3D Cadastres questionnaire, 2014) and Land Administration Domain Model (LADM) standard. However, this study proposes functionalities for 3D cadastre in Serbia they could be an interesting approach for other jurisdictions with similar cadastre background as well.

Section 2 of this paper provides a review of the current registration of complex 3D situations in Serbia, including examples. Section 3 gives an analysis of the proposed functionalities that need to be introduced on the way towards the 3D Cadastre in the Republic of Serbia. The fourth section shows the testing of some of the functionalities using real data examples and showing what can be done with current data provided by licensed surveying agencies. The paper ends with the conclusion.

2. CURRENT REGISTRATION OF 3D SITUATIONS

A 3D situation is found in cases where different real estate entities are located one above the other or they are overlapping each other (Stoter, 2004), which is very common in urban areas. 3D situations can be classified in several ways, depending on the different criteria, but they can also be divided into components that will be used as a basis for describing how 3D situations are registered. We used the following components to describe how 3D situations are registered in Serbia:

- Land parcels,
- Buildings,
- Building units,
- Underground objects, and
- Objects located on several land parcels (bridges, viaducts, etc.)

The term underground object is used for constructions that are located below the surface of the terrain, such as underground garages, underground shelters, underground passages, etc. Underground objects that are part of the building (basement, garage, etc.) are considered to as the building unit category. Category Objects located on several land parcels is comprised of constructions such as bridges and viaducts.

2.1 Land parcels

A land parcel is represented in 2D as polygon feature, but the legal status refers to 3D space, i.e. includes space above and below the surface of the terrain covered by the parcel. Within the real estate cadastre and the legal regulations of the Republic of Serbia, there is no strict definition of how deep below the surface of the terrain and how far above the surface of the terrain extend the rights of owners on land presented through a land parcel. However, the Law on Mining and Geological Explorations (Official Gazette, 2015) defines that mineral resources, groundwater resources, geothermal resources, as well as other geological resources are owned by the Republic of Serbia.

Cadastral maps do not contain vertical representation, i.e., there is no elevation of the terrain, only data defining spatial entities in the horizontal plane are stored. The cadastre contains data on the heights of the reference network but even they are not mandatory (RGA, 2006). In other words, this means that it is very hard to get an idea of the terrain elevation just based on cadastral maps and cadastre database. Similar approaches can be found in other countries (Kitsakis and Dimopoulou, 2014).

When it comes to the utility cadastre, there are stored elevation data at the locations of devices or manholes as well as the utility intersections, but this cannot be regarded as an adequate representation of the terrain elevation (RGA, 2005).

2.2 Buildings

Buildings are registered and visualized on the cadastral maps and within the cadastre database. They are presented on cadastral maps as part of the land parcel including a label that shows the number of floors for a building, and this is the only information in the vertical sense, i.e. indicating somehow building height. Figure 1 shows how buildings are presented on a digital cadastral map. For each building a label indicating the number of floors is provided. For example, П+3 means that building has ground floor + 3 floors.

By inspecting the cadastre database (eKatastar, 2018) it can be noticed that the database contains textual data about buildings such as the number of floors below and above the surface of the terrain. This is also the only information in the vertical sense registered in the cadastre database. The cadastre database does not contain additional geometric characteristics of buildings, so spatial data are only defined on the cadastral map.

It is interesting that jetties in constructions (or cantilevers) are not recorded and are not displayed on the cadastral map if they are above the terrain surface more than four meters and if the distance of the orthogonal projection of the part is less than two meters. Also, the stairs next to the building, terraces and entrances to the basements are recorded when their dimensions are larger than 2 mm × S (Miladinovic, 2004), where S is a scale denominator of the cadastral map.

Figure 1. Land parcels and buildings on the digital cadastral map (GeoSerbia, 2018)

2.3 Building units

Building units (flats, basements, garages) are not presented on cadastral maps and one cannot have an insight into the data on them by reviewing the cadastral map. A similar situation is with the cadastre database, because spatial data for building units are not stored. Only useful spatial information available for building unit is the number of a floor where the unit is located, including the ID of the unit within the building. In other words, one cannot determine the spatial characteristics of a particular part of the building by reviewing the cadastral map and the cadastre database.

However, for building units to be registered in real estate cadastre it is necessary to do a survey before the registration. The collected geometry of each building unit remains as part of the technical documentation that is not publicly available and geometry data are not stored in the cadastre database. Based on building unit survey, only net area and other textual data are registered in the cadastre database.

By analysing the legal regulations (Official Gazette, 2009, 2016) and the practice of registration (eKatastar, 2018) of building units, it is noted that, looking from the context of the 3D cadastre, one of the major shortcomings is the lack of the registration of building units that represent common property (staircases, hallways, etc.). In other words, when registering units of a residential building, only flats, offices, garages, etc. are registered. All other parts of the building that represents a common property remain unregistered.

2.4 Underground objects

Underground objects can be divided into two types: a) underground facilities that are an integral part of a building (basement, garage, etc.) and b) underground structures that represent independent facilities (underground shelters, special underground garages, underground railway stations, etc.). Underground facilities representing an integral part of a building are registered in the same way as other building units. This means that they are not visualized on the cadastral map, while descriptive data is stored in the cadastral database, including unit’s ID within the building, unit’s net area, and unit’s floor number.

Data on independent underground structures are linked to the land parcel where the main or one of the entrances of the structure are located (Official Gazette, 2016). An entrance to an underground structure is often shown as a building, i.e., on the cadastral map is represented by the polygon as for any other building (Figure 2 - Entrance 1), while the parts of the underground structure (shops) are stored into the cadastre database and connected to the entrance feature (Entrance 1). This is done in the same way as building units registration (see section 2.3).

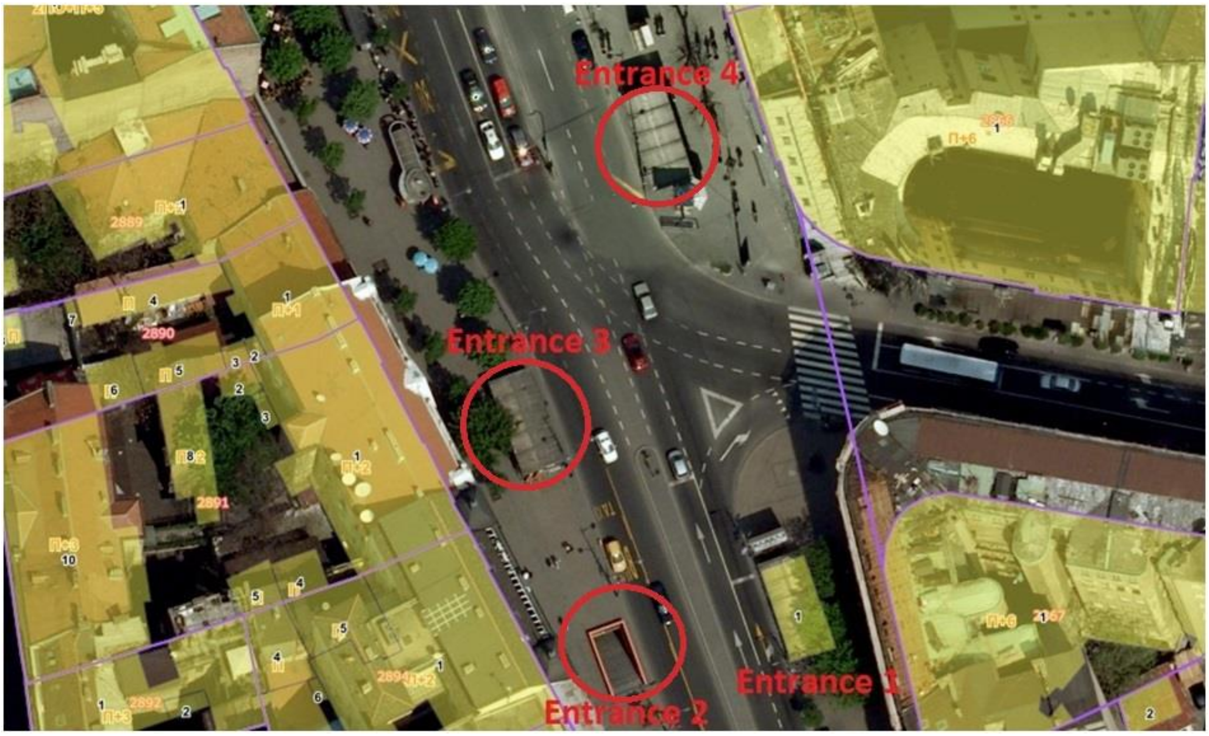

Figure 2. An underground pedestrian passage on the digital cadastral map and orthophoto (GeoSerbia, 2018)

Figure 2 shows how the underground pedestrian passage at Terazije in Belgrade is presented on the digital cadastral map. Based on Figure 2 it can be noticed that only one entrance (Entrance 1) is presented, while the other three entrances (Entrance 1, Entrance 2, and Entrance 3) are not registered on the cadastral map. Entrance 1 is presented in the same way as other buildings on the cadastral map, i.e., as a polygon feature.

The underground pedestrian passage also contains offices (shops) that are parts of the same construction. These offices are registered within cadastral databases (eKatastar, 2018) and connected to Entrance 1 (without geometry, only textual data). Based on the stored data, i.e., the unit’s number within building and unit’s net area, it is evident that space used as pedestrians zone is not registered. Only offices are registered. This means that it is not possible to determine the shape, dimensions and the area of the entire pedestrian passage just using data from the cadastral map and the cadastre database.

Tunnels can be considered as a separate category from other underground objects because they are significantly different in their design and usage, and generally pass under multiple land parcels, which often results with 3D situations.

Regulations in Serbia (Official Gazette, 2016) do not explicitly define the way how tunnel should be registered in the real estate cadastre. It is defined that the data on underground objects (including tunnels) are to be linked to the land parcel where the main or one of the entrances of the object is located. It means that information below which land parcels the specified tunnel passes below is not registered, and also it means that only one entrance to a tunnel can be registered.

Figure 3. The location of the Terazije tunnel on orthophoto and cadastral map (GeoSerbia 2018)

The lack of adequate legislation for tunnels structure registration has resulted in a number of tunnels not being registered on the digital cadastral map and in the cadastre database. This means that there is no information on a tunnel, on land parcels where tunnel entrances are located, and on the land parcels under which tunnel passes by.

A good example is the Terazije tunnel, which is located on one of the most important and busiest street in Belgrade. It is a tunnel that connects two important parts of the city. Figure 3 shows the location of the tunnel (shown in a red, dashed line) on orthophoto and on digital cadastral map.

By reviewing the digital cadastral map, it was found that the tunnel is located in the cadastral municipality Stari Grad and that the tunnel passes below the following land parcels: 2155/1, 2154, 2925, 2918, 2924, 2885, 2814, 2820, 2819, 2809/1 (Figure 3). The entrances to the tunnel are located on the 2155/1 and 2809/1 land parcels. There are no features on these parcels that represent the entrances to the Terazije tunnel. By inspecting the cadastre database, it was found that there are no data on Terazije tunnel at all. In short, the Terazije tunnel, as one of the most important infrastructure objects in Belgrade, is not registered in the real estate cadastre, which means that it is not possible to find information about the tunnel on the cadastral map or in the cadastre database.

2.5 Objects located on several land parcels

This category involves bridges, viaducts, overhead pedestrian crossings and other structures that cannot be classified into any of the pre-processed categories. Usually, these objects are built on two or more land parcels and are located above other land parcels.

As defined by legal regulations (Official Gazette, 2016), if an object is built on two or more land parcels, the data on the object are linked to the land parcel on which the object is mostly built. In the cadastre database, a note is registered stating that the object is located on several land parcels. Other object’s data are not linked to other land parcels. There is only a note stating that part of an object is located on that land parcels.

Applied to bridges, viaducts and overhead pedestrian passages (as representative examples of this type of objects), this means that all data pertaining to an object will be linked to one land parcel, including notes stating that the object is built on several parcels.

This way of registering objects that are located on two or more parcels has been defined by the legal regulations (Official Gazette, 2016) since the year 2016. The legal predecessor of this regulation (Official Gazette, 1999) does not define the method of registering objects, such as bridges and viaducts, that are located on two or more parcels or located above other parcels.

Therefore, the regulation of registration of objects such as bridges, viaducts, and overhead pedestrian passages was not clearly defined. As a result, the cadastre system in Serbia does not provide any adequate data on these type of objects.

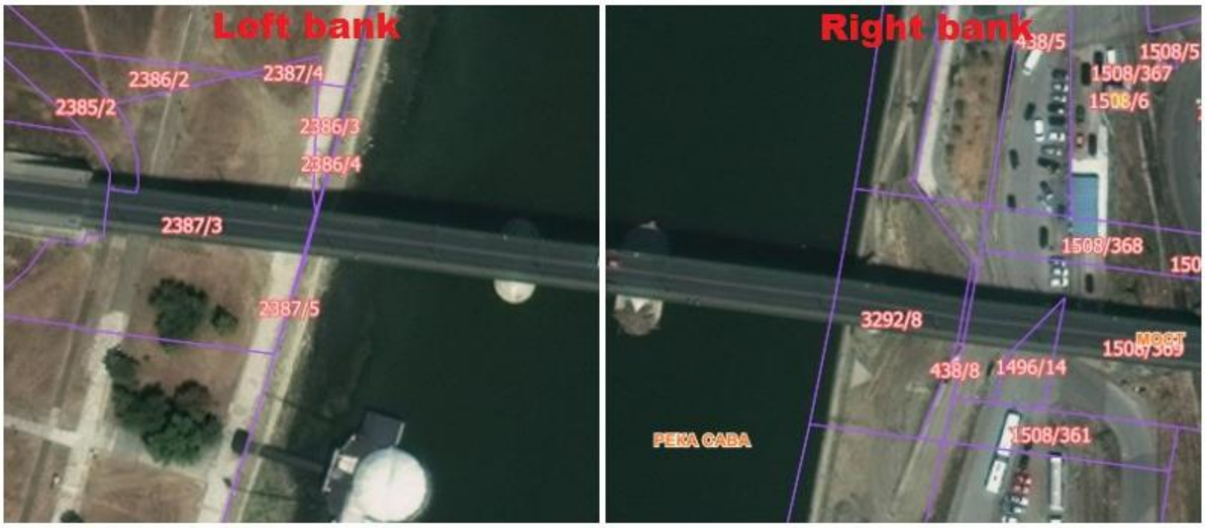

Figure 4. Old Sava Bridge (the left and right Sava bank) on overorthophoto and cadastral map (GeoSerbia, 2018)

Figure 4 shows how the Old Sava Bridge is presented on the cadastral map. By reviewing the cadastral map, it was found that the land parcel representing the Sava river does not contain any data on the bridge. The only information on the bridge is the label "MOCT" (means bridge) located at the beginning of the bridge from the right bank (Figure 4, right edge).

3. PROPOSED FUNCTIONALITIES TOWARDS 3D CADASTRE

In the previous section the main challenges of the Serbian Real Estate Cadastre when it comes to registering 3D situations were considered. In order to overcome these challenges, it is necessary to introduce a number of functionalities and to expand the possibilities of the current real estate cadastre.

Based on legal regulations and the current practice in Serbia, international practices, and standards we propose a set of functionalities which will start the transition of Serbian cadastre system toward 3D cadastre in the short to medium-term time period. We will describe these functionalities according to five real estate components categories that are used in the previous section: land parcels, buildings, building units, underground objects and objects located on several land parcels.

3.1 Land parcels

There are several approaches for 3D Cadastre implementation. In relation to the specific country, the selected approach will also define the scope of the implemented 3D cadastre. So the following questions can be raised: "What is the type of 3D objects that will be registered?", "Do 3D objects always refer to constructions (i.e. buildings, tunnels) or they can refer to any part of the 3D space?", i.e., space above and below the surface of the terrain (van Oosterom, 2013).

When it comes to land registration, an analysis of both approaches can be found in the literature. The study (Stoter et al., 2004) provides an overview of a full 3D cadastre approach with the analysis of a 3D parcel and the role of a land parcel defined on the surface of the terrain. Recent studies also deal with 2D land parcels (Thompson et al., 2017) and 3D parcels (Stoter et al., 2017) in different contexts.

Current real estate cadastre in Serbia contains about 18 800 000 land parcels (RGA, 2018). In view of this fact, it can be expected that the use of these parcels will continue over a longer period of time. Furthermore, we do not expect that concept of a full 3D Cadastre (with a variation of 3D parcels) will be introduced in the short to medium-term period of time. Therefore, we propose that 3D objects refer to real-world objects whereas land parcels should be registered by using 2D polygons, in the same way as it is done currently.

In order to start the transition towards a 3D Cadastre, the first step may be the registration of heights (elevations) at land parcel nodes, i.e., adding heights to the current coordinates on the cadastral map. A similar conclusion is also provided in other studies (Jaljolie et al., 2018; Drobež et al., 2017). The study of Navratil and Unger (2013) underlines accuracy requirements for the 3D cadastre height systems. This can be done in stages during the process of creating new land parcels or by resurveying existing data. In addition to specifying elevations for land parcel nodes, it is necessary to collect elevation points for all structural lines of the terrain located within the land parcel. If collected points do not provide a realistic representation of the terrain, it is necessary to collect additional height points (Figure 5).

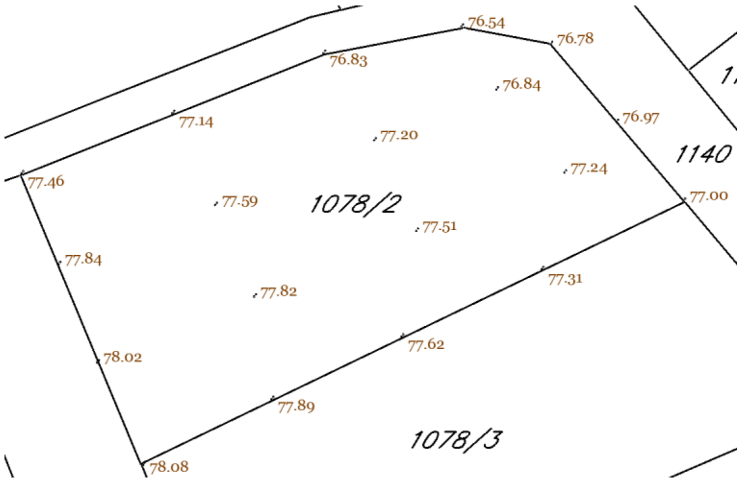

Figure 5. An example of the necessary height points for the land parcel

Height data are very important and today surveyors can collect data for the introduction of a third dimension without additional costs of the field works (Drobež et al., 2017). Based on collected height points it is possible to create a digital terrain model that would represent an auxiliary dataset used for visualizing purposes.

It is interesting that for a number of land parcels height points can be calculated without an additional survey. Heights can be calculated using tachymetric observations and other sources already provided in former surveying records. They just need to be calculated and introduced into the cadastre database data model and digital cadastral map database. There is the similar claim for Slovenia case (Drobež et al., 2017) which has a similar cadastral background as Serbia. Introducing the heights into Serbian cadastre system does not require changing the legal regulations, so from this point of view, it is a feasible goal in a short-term time period.

Additionally, as proposed by the study (Navratil and Unger, 2013), information on the actual accuracy of height points should be stored also, since data will not have homogeneous accuracy (Erba et al., 2014). This can be done by introducing accuracy levels.

In other words, the real estate cadastre will register a set of points (X, Y, H, accuracy level) with a well-established order in such a way to form a polygon of the land parcel. In addition to these points, height points representing the structural lines of the occupied terrain (also with X, Y, H data, accuracy level) should be recorded.

Enabling the possibility to define how far above and how deep below the terrain surface the rights on land parcel extend would contribute to a clearer registration of 3D situations. Similar was advised in the study (Karabin, 2014), while (Gulliver et al,, 2017) noted that 2D spatial units can be viewed as a column of space unbounded above and below.

We are aware that introducing only heights and possibility to bound land parcel in a vertical sense will not solve all challenges, but we see it as something that is feasible in the short to medium-term period of time.

3.2 Buildings

Serbian cadastre system contains around 4 800 000 buildings (RGA, 2018). Most of them are simple buildings, located within one land parcel and they are not involved in the formation of complex 3D situations. Having in mind the goal of 3D cadastre implementation within a short period time, it can be concluded that introduction of buildings' heights would be the simplest and fastest step towards the 3D cadastre (by using mass-collecting methods such as LiDAR). The authors of the study (Kitsakis and Dimopoulou, 2014) also noted that we need the height of an object to assign volumetric aspects to the object. The study (Drobež et al., 2017) proposed that both absolute and relative heights should be stored in 3D cadastre. Besides the heights of a building, it would be useful to store the height of the lowest point in a building, because it will provide possibilities to calculate how deep below the surface is building located. This is not so simple as getting the building height but it can be introduced in the short-term time period and implemented in the medium-term time period. This information should be mostly based on available technical documentation and Building information modeling (BIM) projects. This step towards 3D Cadastre does not require changes in laws and regulations.

In order to overcome the challenges of the current cadastre system in Serbia, when it comes to the buildings that form complex 3D situation, it is necessary to introduce the concept of a 3D object, i.e. registration of buildings and other objects by using 3D geometry.

The preceding section mentions the dilemma: "Does a 3D object always refer to a real-world objects or it can refer to any part of the 3D space?". Furthermore, a question can be raised: "If related to real-world objects, how can the relationship between the 3D cadastral registration (legal spaces) and the registration of real-world objects be maintained?" (van Oosterom, 2013). The authors (Aien et al., 2013) provide the study that describes the possibility of integration of 3D legal and physical objects in one model. Also, they noted that there is no integrated cadastral data model that can maintain both 3D legal and physical objects. City models can provide 3D physical objects, whereas cadastral systems (such as LADM based ones) maintain legal data. When it comes to legal space, determined by a boundary, it shows where a right or a restriction ends and where the next right begins (Kaufmann and Steudler, 1998). Introduction of 3D objects that will refer to a real-world objects and represent legal space is possible in the medium-term time period.

The object represented as a 3D object is recorded by its legal dimensions and presented as a set of surfaces that form a closed body. LADM standard proposes using MultiSurface geometry to represent 3D objects, while the study (Aien et al, 2013) provides discussion comparing multisurface geometry and solid geometry for 3D cadastre needs.

This functionality will not require a change of lows but it will require changes in some of the instructions provided by Republic Geodetic Authority of Serbia. Furthermore, for some of the buildings (mostly buildings with building units) necessary data already exists within the technical documentation that is not publicly available. The data just needs to be converted and introduced into the cadastre data model. Figure 6 shows an example of data provided by licensed surveying agency for the purpose of building registration. Case study 1 shows how the same data can be used for creating a 3D object.

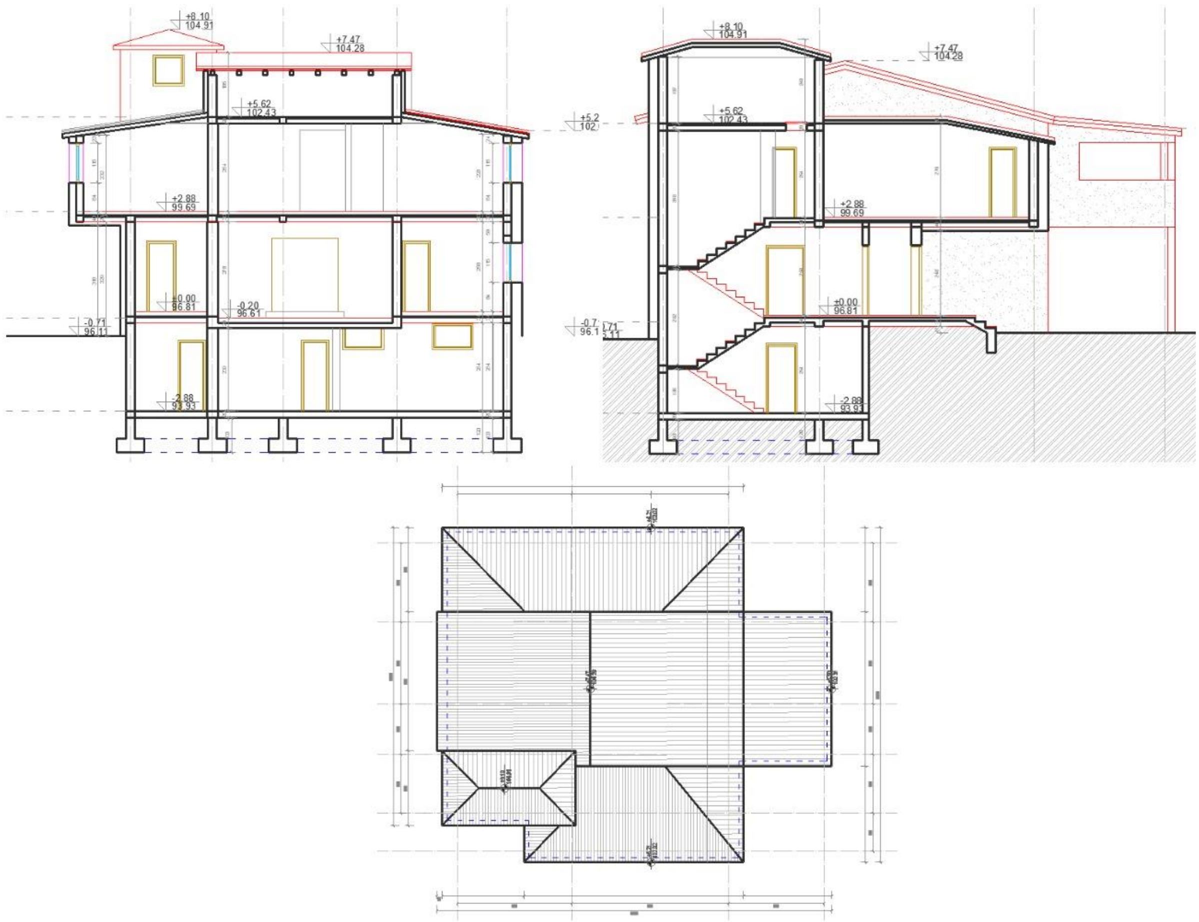

Figure 6. Example of data provided by licensed surveying agency

3.3 Building units

When it comes to building units, the first thing that can be changed is that the volume of buildings that are made up of special parts must be divided into separate units. This means that building units that are common property (staircase, hallway, etc.) should also be registered. Introducing this aspect at the level of current building unit registration (without geometry, only net area and textual data) can be introduced in the short time period.

The following functionality could be the introduction of geometry representations of building units. Building units can be presented using 2D or 3D geometry. If a building itself is represented by 2D geometry, then the parts of a building should also be represented by using 2D geometry (within the floor plan). On the other hand, if a building is represented by 3D geometry and parts of a building cannot be unequivocally represented by floor plan, then 3D geometry should be used. Proposed 3D geometry is set of surfaces as proposed by LADM standard. For floor plans, in addition to their 2D geometry, it would be useful to store the absolute and relative height of each floor.

When registering a specific part of a building, it is necessary to determine its limits, i.e., the border that represents the legal possession limits in space. In other words, the geometry that is registered in the real estate cadastre is the legal property rather than the physical size of the object (e.g., the boundary between the two parts of the building is the middle of the wall). However, the study (Aien et al., 2013) noted that the different level of detail of physical information is required for different needs.

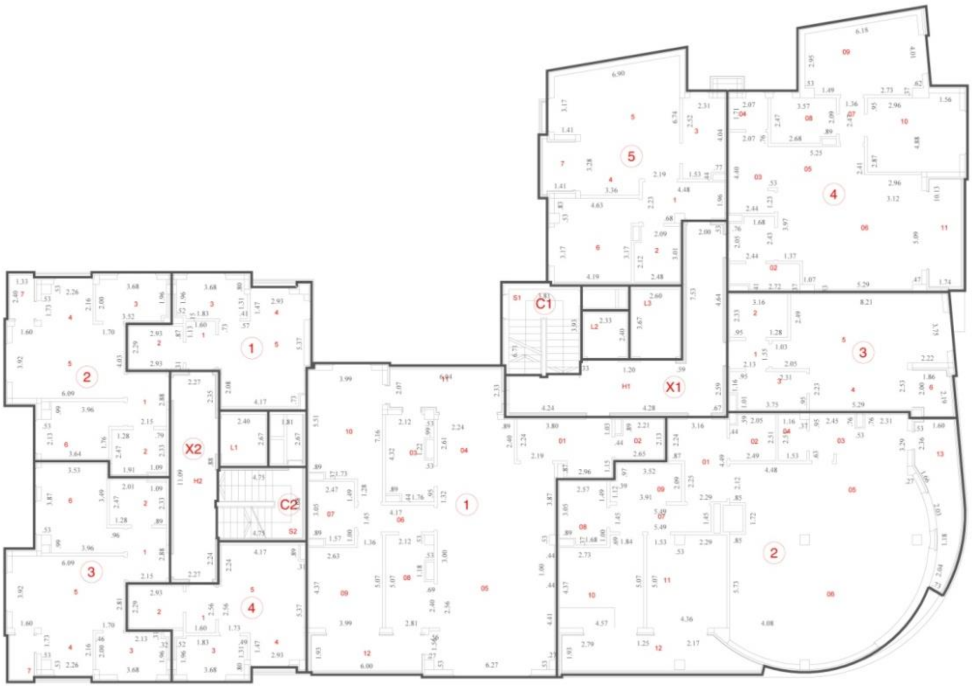

Figure 7. Floor plan provided by licensed surveying agency

Data for geometry representation of building units already exists for some of the registered buildings. They are provided by licensed surveying agencies as a part of the technical documentation that is not publicly available. It is in a form of floor plans (Figure 7) or other drawings such as cross-sections (Figure 6). Authors of the study (Aien et al., 2011) identified some of the complexities in similar data sources, such as that the location of cross-sections depends on the surveyor's decision. These complexities are also valid for the Serbian case.

Building units located below the surface of the terrain (basements, garages, etc.) are registered in exactly on the same way as the other parts of the building. Registering building units with its geometry requires changing instructions provided by Republic Geodetic Authority and extending existing cadastre database data model. 2D geometry representation can be implemented in the short time period while 3D representation can be implemented in the medium-term time period.

3.4 Underground objects

Underground objects that represent independent facilities (underground shelters, underground garages, underground railway stations, etc.) require a different approach. Such facilities can be located under a number of land parcels. As a result, for each land parcel above an underground object, it must be registered that an underground object occupies a part of the parcel's space. Furthermore, all entrances to an underground object should be registered (not only one entrance as so far). This can be implemented in the short to medium-term time period and requires changing of regulations such as "Regulations on Cadastral Survey and Real Estate Cadastre" (Official Gazette, 2016).

Unlike buildings, an underground object should be represented only by 3D geometry, i.e., through a set of surfaces that form a closed body. The boundary of the object consists of the outer walls. If it is not possible to measure the thickness of the walls, this information can be taken from technical documentation. If an object requires the use of space larger than its physical dimensions (for example, the tunnel belt), that space should be registered as an expanded geometry of the object and use it to represent the legal space that the object occupies. A similar explanation can be found in the study (Guo et al, 2013). Combination of 2D land parcels and a 3D underground object will not solve all problems and provide unambiguously registration of these properties. However, we propose this as the first step toward full 3D cadastre which can be implemented in the medium-term time period and it also does not require big changes in laws and regulations.

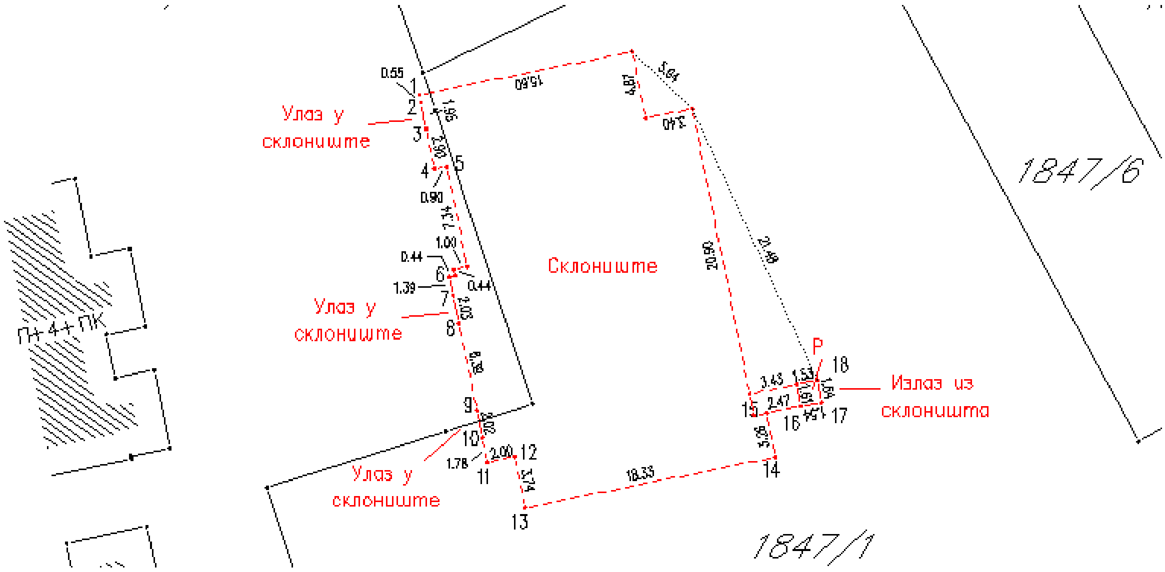

Figure 8. Example of spatial data for an underground object provided by licensed surveying agency

Regarding the spatial data, surveying agencies currently do not provide all the necessary data for creating a 3D geometry of an underground object. They mostly provide data of interior object space projected in 2D. This means that additional data sources will be required. Figure 8 shows an example of spatial data provided by licensed surveying agency.

3.5 Objects located on several land parcels

Since these objects extend over several land parcels, it is necessary to enable their registration on all these parcels, i.e., to change the current practice where an object is registered only on the land parcel on which the object is mostly built. The most common situation with this type of objects is that the foundations of the object are located on several land parcels (for example, carrying pillars of the bridge). In this case, it is necessary to create parcel parts for these foundations. In addition, for each land parcel located below an object, the information that the object occupies part of the parcel's space above the terrain surface needs to be stored.

This can be introduced by changing regulations on the cadastral survey and can be done in the short to medium-term time period.

Regarding the geometry, we propose using 3D geometry. Using 2D geometry for objects such as bridges would also result in unclear representation. Similar to underground objects, a combination of 2D land parcels and a 3D object will not solve all problems and provide unambiguously registration of these properties. However, it would represent the first step towards 3D cadastre and it can be implemented in the medium-term time period by making some necessary changes in regulations and extending the current data model.

There is no much spatial data on these objects provided by surveying agencies. Most of the data required for creating 3D objects will have to be surveyed or taken from other sources.

3.6 Functionalities overview

By analysing the proposed functionalities, we have come to the conclusion that many improvements can be done in the short to medium-term time period. However, solving all challenges that the current cadastral system has will probably have to wait for full 3D cadastre implementation. This could be done only in the long-term time period. Table 1 summarizes the proposed functionalities and shows what is possible to achieve in the short to medium-term time period.

Table 1. Functionalities overview

Category	Functionality	Short-term period	Medium-term period	Long-term period
Land parcels	Heights at land parcel			
	Vertical bound of land parcel			
Buildings	Building highest point			
	Building lowest point			
	3D object			
Building units	Common property registration			
	2D geometry of building units			
	3D geometry of building units			
Underground objects	Land parcel space occupation			
	3D underground object			
	Registration of all entrances			
Object on several land	Object connected to all parcels			
	3D object			
Full 3D cadastre	LADM based, 3D objects, etc.			

Besides this functionalities, many shortcomings of Serbian cadastre system, such as the lack of interoperability, mismatch of spatial and textual data, or lack of an integrated cadastral information system will be solved by introducing a system based on the LADM standard (Radulović, et al. 2017). The LADM standard supports both 2D and 3D geometry (Thompson, et al. 2017) (Stoter, et al. 2013), so the implementation of LADM standard into Serbian cadastre system does not need to wait for the implementation of the full 3D Cadastre. The LADM based full 3D cadastre system should be an aim for a longer period of time.

Furthermore, one of the main reasons why the real estate cadastre and the utility cadastre in Serbia are separate registers is the fact that representing the content of both registers on paper-based maps would lead to unreadable maps. However, the digital full 3D Cadastre will not have such a problem. In digital space, it is possible to filter data in order to visualize only desirable content while integration of these registers will lead to a better understanding of a property space. A future full 3D cadastre system should include utility data as well. Authors from Croatia proposed overlapping Land cadastre and Utility cadastre (Vučić, et al. 2014).
All data stored in a cadastre system, 2D or 3D based have to be validated by using well-understood methodologies. It is also important for future Serbian 3D Cadastre system. The study (Karki et al, 2013) shows an insight into the validation requirements for both 2D and 3D cadastral data in Queensland, Australia case.

4. CASE STUDY

For some of the proposed functionalities examples are provided with actual cadastral data stored in MongoDB (NoSQL database) and visualized by using the Cesium library, as represented in the study (Višnjevac et al, 2017).

4.1 Case 1

Case 1 is a building located in Stojana Ljubica street in Belgrade. The data and technical documentation were provided by a licensed surveying agency (see Figure 6). The provided data was enough to create a 3D object that represents legal space on which a right is registered. This suggests that introducing 3D objects for buildings with similar technical documentation is possible in the medium-term period.

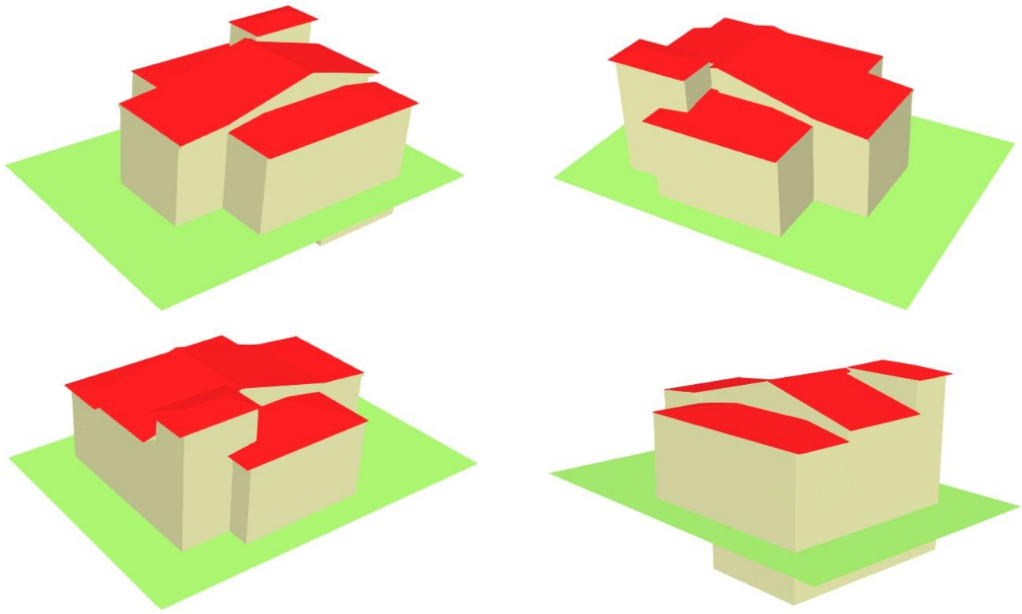

Figure 9. 3D object that represents legal space of a building created based on data provided by surveying agency

In addition, it is noticed that there is no strict standard about technical documentation that surveying agencies provide. So, standardization of technical documentation is also required in the very near future.

4.2 Case 2

Case 2 is a building and building units located in Dimitrija Tucovica street in Belgrade. 3D objects of building units legal space are successfully created based on data and technical documentation provided by a licensed surveying agency (see Figure 7).

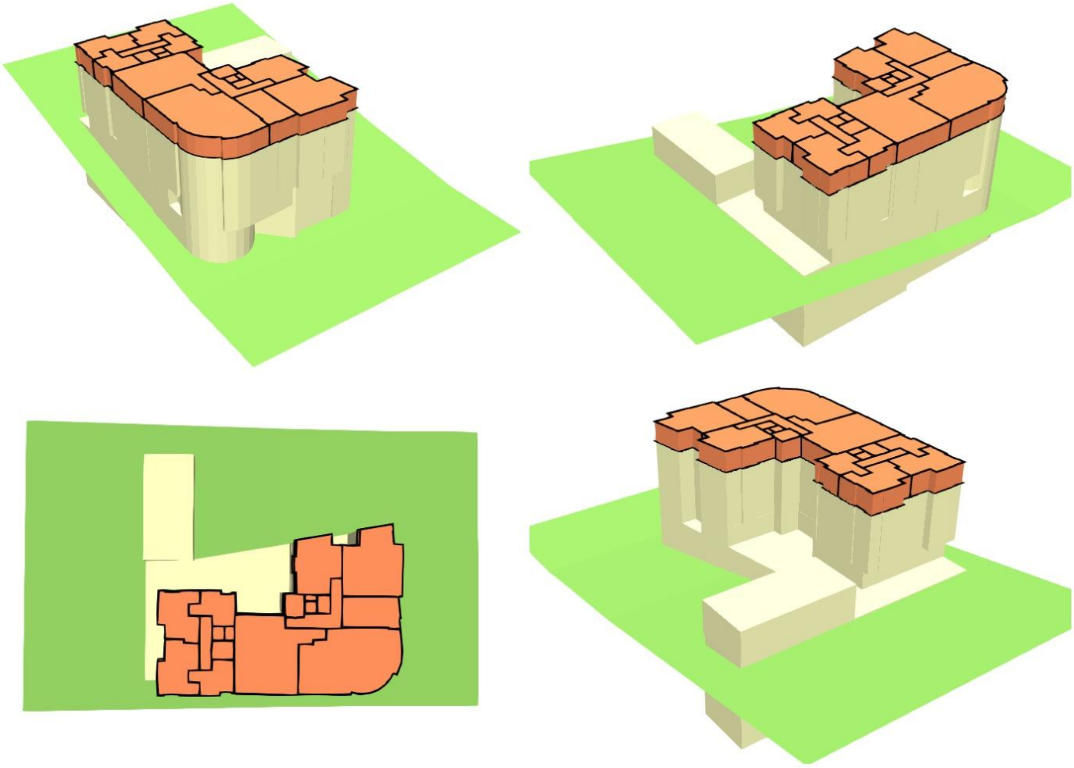

Figure 10. 3D objects representing legal space of building units created based on data provided by surveying agency

Data on building units provided by surveying agencies are not strictly standardized, but in most of the cases they can be used for the creation of 3D legal space for building units.

4.3 Case 3

Case 3 represents the underground shelter located in the Jablanicka street in Belgrade (Figure 11). The data provided by surveying agency was not enough to create a 3D object that represents legal space. The data was adequate only for creating interior space of the object.

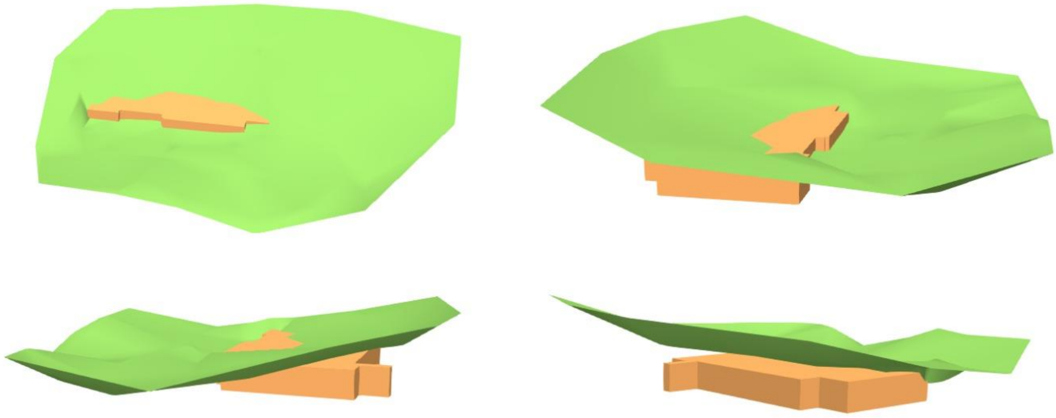

Figure 11. 3D object that represents the interior space of the underground shelter

This means that additional surveying or other data sources are required. Furthermore, height points provided by surveying agency are used for terrain visualization. For this purpose, the terrain model was created. Based on the visualized terrain (Figure 11) it can be concluded that the number of height points was not enough and additional surveying is required.

5. CONCLUSIONS

This study presents the challenges and proposes directions for the development of Serbian 3D Cadastre system. It is concluded that full 3D cadastre will overcome all current challenges of Serbian Cadastre system when it comes to registration of complex 3D situations. However, by analysing experiences from other countries, and current practice and legal regulations in Serbia, we concluded that full 3D cadastre would not be implemented in the short to medium-term time period. It is in perspective for long time development.
Having in mind all of these conclusions, a set of functionalities were proposed that can be implemented in the short to medium-term time period. That will also trigger the transition from the current cadastral system to a 3D cadastre system. Overview of functionalities is provided including proposal what can be done in the short-term and what in the medium-term time period. Development of these functionalities must be followed by developing methodologies that will be used for data validation. Within the case study, it is demonstrated that data currently provided by licensed surveying agency can be used for 3D cadastre purpose. Future development (long-term period) will include the development of LADM based full 3D cadastre system including integration of real estate cadastre and utility cadastre.

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