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3D CADASTRAL DATA IN THE PROCESS OF URBAN PLANNING

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ABSTRACT

Cadastral data are very important in the process of urban planning. Moreover, cadastral data present a spatial base for urban planning decisions. Over the last few decades, research on 3D cadastres have been performed raising worldwide awareness of the need for 3D cadastral systems. This was driven by the development of new technologies for the acquisition, storage, maintenance, and visualization of 3D data as well as by complex situations in urban areas that cannot be unequivocally registered in 2D based cadastral systems. This paper examines the 3D cadastral data and emphasizes the differences between traditional cadastral data and 3D cadastral data. An overview of 3D cadastral systems was provided, the basic description of 3D cadastre data, and examples of the real situations that traditional cadastral systems cannot handle and unequivocally register. The paper further presents what would be clear benefits for urban planning once the 3D cadastre system is implemented. It is emphasized how important is 3D geometry and data on ownership for underground constructions and utility networks. Conclusions were provided and what needs to be fulfilled to effectively use 3D cadastral data in the process of urban planning.

Keywords: 3D cadastre, urban planning; land administration; modelling

1. INTRODUCTION

During the last century, modern cities become highly populated urban areas with property units located above and below the ground. There are also complex 3D situations when two or more properties overlap each other. This has resulted in many obstacles for traditional 2D cadastral systems because these 3D situations and objects are registered and represented in 2D cadastral maps and projected into the horizontal plane. All of these restrict the registration and presentation of urban property units. In other words, 2D cadastral plans can become ambiguous, and certain complex structures cannot be represented in an unequivocal way (Višnjevac et al, 2019; Petronijević et al, 2021).

The development of modern technologies (3D Geoinformation systems, 3D visualization, Building Information Models, etc.), has initiated significant research on 3D cadastres (Van Oosterom, 2013; Van Oosterom et al, 2018) and that opened the space to solve difficulties with registering and representing complex 3D situations and objects.

3D Cadastre as a new concept is still in the development stage. The type of 3D Cadastre system, its basic definition, and implementation highly depend on the legal system of a county, previous cadastral system, and economic and technical potential. It is important to emphasize that cadastral data contain legal data. In the context of 3D Cadastre, it is a legal space and not necessarily physical object boundaries (Višnjevac et al, 2018).

On the other hand, cadastral data represent the basis for urban planning and urban plans define a new parcel structure so there are strong ties between cadastral data and urban planning. 3D cadastral data will bring more

quality to the urban planning process. By solving difficulties that the current cadastral has urban planning process will gain a better and more clear basis.

The rest of this paper is organized as follows: Section 2 describes the role of cadastral data in the process of urban planning. Section 3 contains the description of the current state, ie. traditional cadastral systems, and examples of the real situations that traditional cadastral systems cannot handle and unequivocally register. Section 4 presents an overview of 3D cadastral systems and the basic description of 3D cadastre data and emphasizes the differences between traditional cadastral data and 3D cadastral data. At the end of the paper, the conclusion and discussion were provided.

2. CADASTRAL DATA IN THE PROCESS OF URBAN PLANNING

A cadastral system containing cadastral data represents the basis for urban planning. It is inconceivable to start making an urban plan without the proper cadastral data. There are two aspects that the importance of cadastral data for urban planning can be observed.

First, in order to obtain relevant and up-to-date data on land, the cadastral maps and other cadastral data must be analyzed. Besides the parcel boundaries and buildings, the cadastral system contains other information about the land. Most cadastral systems in the world contain data about property rights of the parcels and buildings, values of land and buildings, the way of use, fertility, etc. The modern approach to the cadastral system tends to make it as multipurpose as possible. Because of that, the content of the cadastral systems can be the data in the fields of ecology, meteorology, even sociology, and so on. So, besides geometry data, which is crucial for urban planning, the cadastral system contains other data that can be important for designing urban plans.

Second, the implementation of urban plans inevitably leads to a new parcel structure with new parcels and parcel boundaries. In order to create new parcels and make them official, in accordance with the existing legislation, the coordination between the plan implementation and cadastral records must be obtained.

Besides that, the coordination with the cadastral system provides that the whole process of urban planning goes efficiently. There are many formal phases in the process which can be time-consuming and even sometimes may appear like insoluble obstacles. In most countries, the cadastral system is designed in a way that it serves as support to urban planning in terms of dealing with formal phases of the process.

The importance of cadastral data for urban planning can be seen when analyzing the examples of unsuccessful plan implementation in countries that have problems with outdatedness of cadastral data (Šoškić et al, 2022). In those cases, data recorded in the cadastre can significantly deviate from factual data on the ground. The main question is: would the experts who made the urban plan make it differently if they had the updated data? Unfortunately, the answer is found at the end of the process of implementation of an urban plan. That leads to the inapplicability of urban plans in practice and collapses the whole system.

After this being said, it is obvious that the role of the cadastre in urban planning is indispensable, and that there is no successful urban planning without a good and up-to-date cadastral system that can, not only provide quality data but also to support the whole process of urban planning.

3. CURRENT STATE – TRADITIONAL CADASTRAL SYSTEMS

Traditional cadastral systems contain 2D cadastral maps with land parcels as a base. Land parcel ID is the main identificatory. Additionally, to the cadastral map, there is a cadastral database that contains all other information on properties. In recent decades, many countries digitalized the cadastral maps and integrated them with the cadastral database. However, usually only 2D geometry data are presented.

It means that traditional cadastral systems have a number of difficulties to register and visualize complex 3D situations that are very common in densely populated urban areas. Depending on different criteria, 3D situations can be classified in several ways, but they can also be divided into components such as terrain, buildings, building units, underground constructions, constructions over or under several land parcels, etc. The following paragraphs contain a description of how these components are registered in the case of the cadastral system in the Republic of Serbia. The description is also valid for many countries that have similar cadastral system.

Terrain is not presented on the cadastral maps, there is only a representation of properties in 2D space. When comes to heights, the cadastral database contains only heights of geodetic points. It means that it is very hard

to get an idea of the terrain based only on cadastral maps and other content of the cadastre database. The utility cadastre contains height data on devices, shafts, branching points, etc. However, this cannot be considered as an adequate representation of the terrain.

Buildings are registered in the cadastral database and visualized on the cadastral map. Cadastral maps present buildings as 2D polygons inside a land parcel. They also include descriptions showing the number of floors, which is the only piece of information in the vertical dimension. Figure 1 shows examples of buildings on the digital cadastral map. The cadastral database does not contain any additional information on building height. This information can be found only in project plans.

Figure 1: Buildings on the digital cadastral map

Building units are not presented on the cadastral maps and it is not possible to have an insight into building units' data by looking at the cadastral map. The cadastral database contains descriptive data such as area, usage type, id, etc. There is no additional information that will provide spatial characteristics of a building unit.

Underground structures can be divided into two types: underground structures that are an integral part of another building (basement, garage, etc.) and underground structures that represent stand-alone objects (underground shelters, special underground garages, underground railway stations, etc.). Underground structures that represent parts of a building are presented in the same way as other building units. Stand-alone underground structures are connected to the land parcels where the main entrance is located. It means that the entrance is presented as building (2D polygon) on the cadastral map. Underground structure itself is registered in the cadastral database as a building unit (without geometry). Figure 2 shows an example of an underground pedestrian passage with four entrances. Only main entrance was registered as building on the cadastral map.

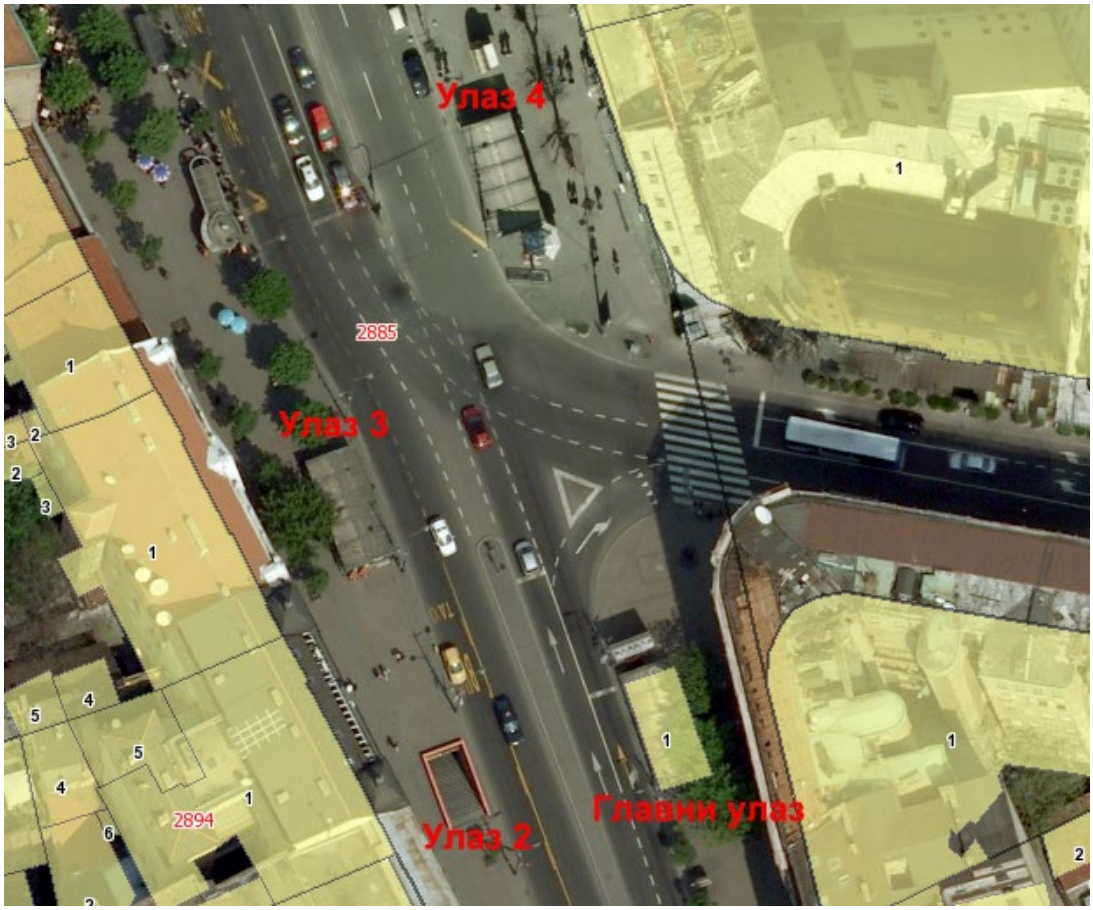


Figure 2: Underground pedestrian passage

Tunnels are specific type of stand-alone underground structures. In many cases they go under several land parcels. Since registering such cases is very hard in the current 2D based cadastral they are usually registered without geometry or not registered at all. Figure 3 shows an example of tunnel (interpreted by red dashed line) which is not registered in the cadastre system.

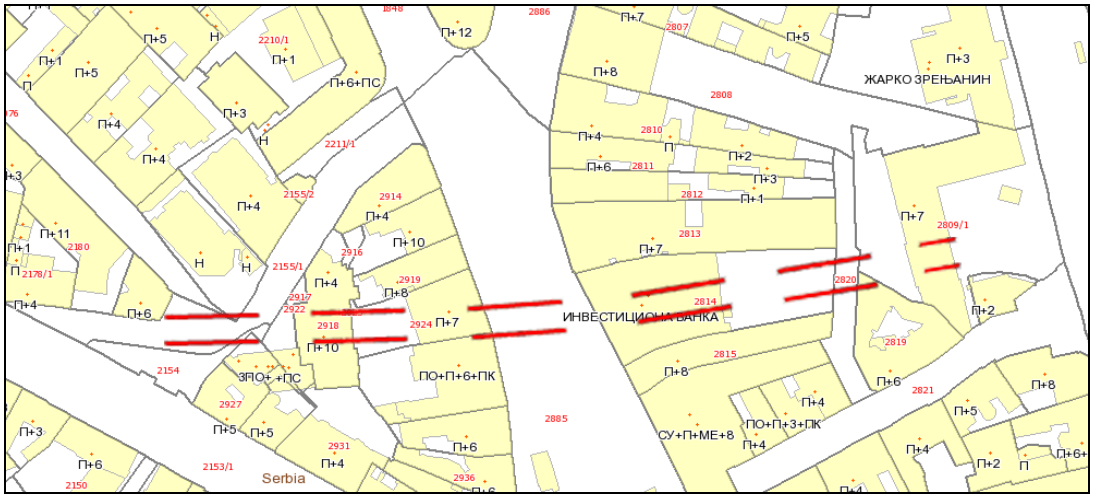


Figure 3: Location of Terazije tunnel in Belgrade

Similar situations are when comes to structures that go over several land parcels (bridges, overpasses, etc.). In many cases they are not registered and it is not possible to get information about them by looking at the cadastral map.

All these examples show that the current cadastral systems have difficulties to unequivocally register and visualize all complex 3D situations. This comes from the fact that the basic spatial unit is a 2D land parcel and

that it is necessary to project and visualize all elements of a complex 3D situation on a 2D surface. This situation has contributed to the fact that many specific structures are not registered in cadastral system.

4. 3D CADASTRE

The basic requirement that a 3D cadastre should meet is to enable overcoming the difficulties that current cadastre systems have when registering and visualizing complex 3D situations and objects. In other words, 3D cadastre systems should enable the registration and representation of rights through 3D entities.

It is very important that the future 3D cadastre be as simple as possible in order to ensure that the system is up-to-date as easily as possible. Up-to-date data in the real estate cadastre is key to the existence of the system itself because it is a public register of real estate and rights to it. A complex system with an overly detailed data model can lead to the fact that in practice it is very difficult to fulfil all the requirements of the system, or that the process requires too many economic resources. If this is the case, it will certainly lead to not updated data and more difficult management of the cadastre system itself.

For the development and implementation of 3D cadastre, it is necessary to pay attention to the additional requirements, such as the integration of the real estate and the utility estate cadastre. It also includes use of different sources for collecting 3D data. Additionally, the 3D cadastre should be implemented in a way that cadastre data can be easily and frequently used by professionals in different fields.

3D cadastre can be developed as a 2D system with 3D tags, a hybrid model, or as a full 3D cadastral registration system (Stoter and Salzmann, 2003). A 2D system with 3D tags is a basic, starting approach and no information on the 3D situation is integrated into the cadastral registration. When comes to a hybrid model, the approach is based on keeping the registration and visualisation in 2D space, but also registering 3D situations as 3D objects including establishing a connection between 2D parcels and 3D objects (see Figure 4). Full 3D cadastral registration system represents the introduction of a completely new concept of registering rights in 3D space, where the entire space is divided into 3D parcels (volumes) that are defined as parts of 3D space. When comes to this approach it is possible to register 3D rights on parts of space that represent separate entities and are not tied to traditional 2D land parcel.

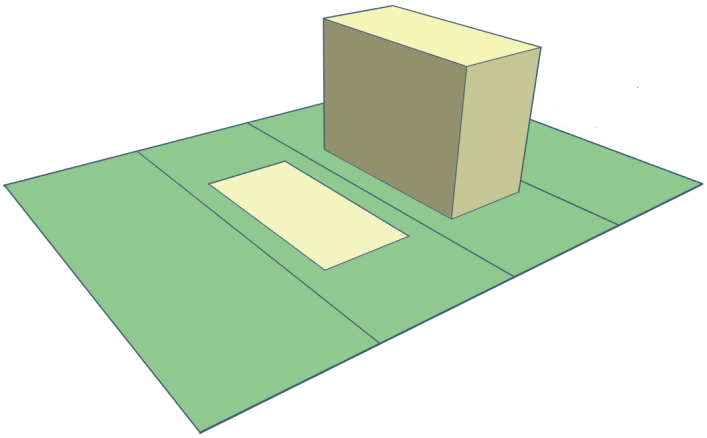


Figure 4: An example of hybrid 3D cadastre elements

By analysing all three approaches, it can be concluded that the hybrid model provides the simplest way to meet the needs and functionalities of a 3D cadastre system. This is based on the fact that by using a hybrid approach it is possible to overcome the difficulties that a 2D cadastre system has when registering 3D situations and at the same time partially use the current 2D cadastre data. This will make the costs and resources needed for establishing and maintaining a 3D cadastre system more acceptable.

4.1. 3D Cadastre Data

If we consider a hybrid model as an optimal solution it means that in addition to current cadastral data there is 3D geometry for complex objects and situations (overlapping properties, underground constructions, structures over or under several land parcels, etc.). 3D geometry can be presented in 2 ways, as a 3D solid body or a set of surfaces that form closed 3D body. Both approaches have advantages and disadvantages, however international standard for the land administration domain propose (LADM) proposes using MultiSurface

geometry to represent 3D objects. The study (Aien et al, 2013) provides discussion comparing multisurface geometry and solid geometry for 3D cadastre needs. Figure 5 shows an example of a set of surfaces (multisurface) that form a closed 3D body.

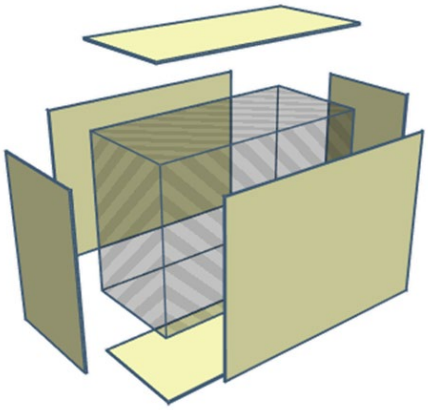
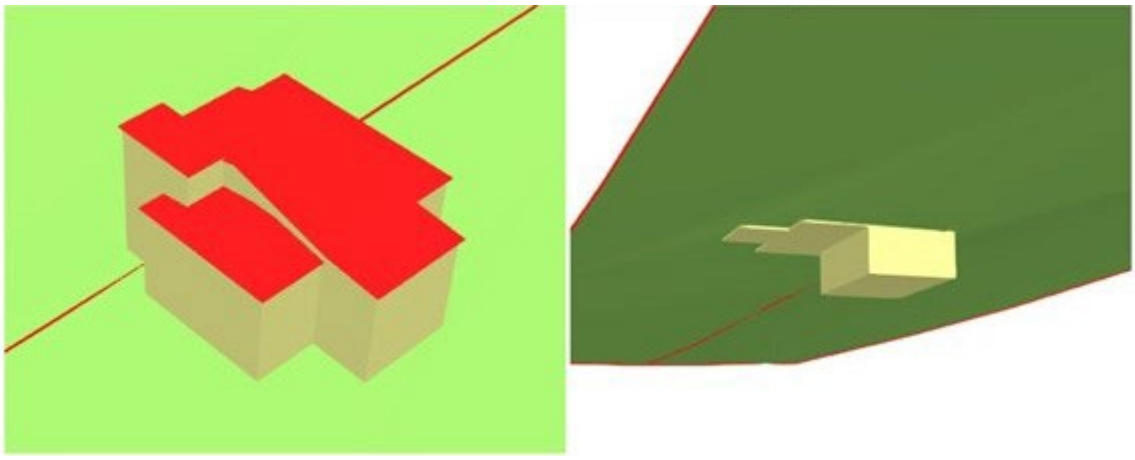


Figure 5: An example of a set of surfaces (multisurface) that form a closed 3D body

In the case of MultiSurface geometry it means that officially in the cadastre register, in addition to horizontal locations, heights of vertexes are stored (X, Y, H). The size of the minimum details on the external dimensions of the object that are measured and registered must be predefined by geodetic authorities.

Comparing to 3D city models which can provide 3D physical objects, 3D 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). It means that in the case of a 3D cadastre an object represented as a 3D object is recorded by its legal dimensions and presented as a set of surfaces that form a closed body. Legal boundaries are important, especially in cases when they are not the same as physical object boundaries or it is hard to detect them, such as underground constructions and utility networks. 3D geometry of legal space for such objects is necessary for unequivocal registration of ownership of such properties.



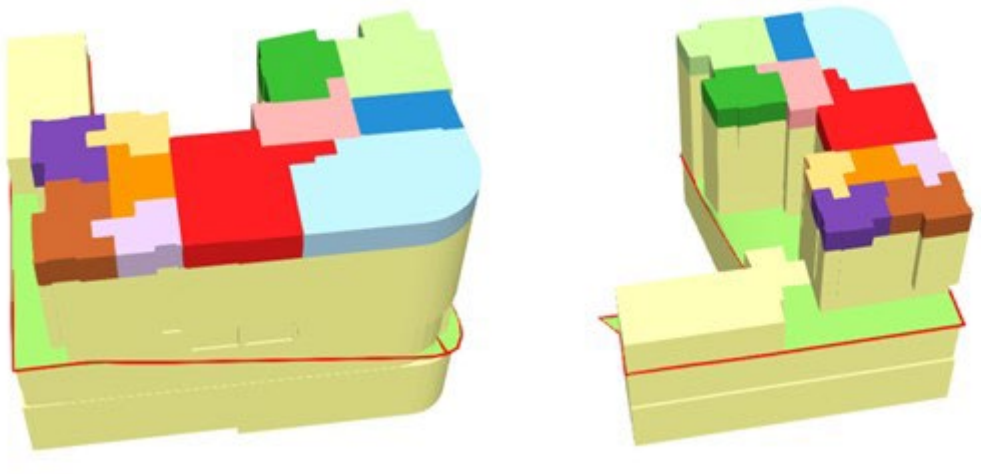


Figure 6: 3D cadastre objects (house with underground structure and building with building units)

5. DISCUSSION AND CONCLUSION

A 3D cadastre is a modern approach to cadastral systems and it enables solving difficulties that traditional cadastral systems face. It is about using modern technologies to improve cadastral systems and enable the acquisition, storing, and visualizing of 3D data (3D objects) that represent legal boundaries. Additionally, it provides the possibility to register, store and visualize complex 3D situations and properties (such as underground constructions or utility networks) by using 3D geometry and to unequivocally register and present where a right (for example ownership) ends and where the next right begins in such cases.

There is still a long way to go until a fully operational 3D cadastre system is developed. Besides new technologies (which are already more or less prepared and ready to support 3D cadastre needs) there is still work on developing data models, procedures and promoting the new 3D cadastre approach. Since 3D cadastre data are going to register legal boundaries there is also work on legislation and that part heavily depends on a country that wants to introduce the 3D cadastre concept. Additionally, since 3D cadastre systems are more complex (because of 3D geometry) than traditional cadastre systems it will require more economic resources to develop and maintain such systems. All this need to be fulfilled to develop a 3D cadastral system and to effectively use 3D cadastral data in the process of urban planning.

In this paper, we emphasized how important are cadastral data in the process of urban planning and that the role of cadastral data in urban planning is indispensable. Moreover, there is no successful urban planning without a good and up-to-date cadastral system. When comes to 3D cadastre and by the fact that this new approach will improve traditional cadastral systems it can be concluded that urban planning will benefit from developing 3D cadastre systems. Since difficulties and ambiguity of current cadastral systems will be solved, it will help and provide better data for urban planning. Additionally, data on underground structures and 3D data on utilities that are not currently available will provide a better basis for urban planning. In other words, professionals in urban planning will have a better picture of what is property situation over and under ground and a clear 3D geometry when properties overlap each other.

Compared to 3D city models, 3D cadastral data will provide legal boundaries data (not only physical object boundaries) which are very important for urban planning and additional focus will be on underground structures and integrating real estate data with utility data and data from other sourses (values of land and buildings, the way of use, fertility, etc). It means that a 3D cadastre will provide information about the 3D space, and depending on a 3D cadastre model it could include legal boundaries and physical object boundaries.

The implementation of a 3D cadastre system will provide a good basis for urban planners to think in 3D space and it will provide additional support to 3D urban plans. Traditional urban plans are 2D based, so with all modern technologies that support 3D cadastre there is also a space to improve and push forward 3D urban planning.

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