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RATIONALE FOR THE INTRODUCTION OF 3D CADASTRE AS ILLUSTRATED WITH THE EXAMPLE OF THE CITY OF KRAKÓW

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Summary

The article presents selected models of 3D cadastre, accompanied by a discussion of the accuracy of the representation of model elements. Research that has been carried out on real data from the Kraków City Council is an attempt at a polemical discourse on the validity and/or necessity of introducing a multi-dimensional cadastre in Poland.

Keywords

real estate cadastre • 3D cadastre • GMLCity

1. Introduction

In Poland, the concept of land and building records has been defined by the Geodetic and Cartographic Law [Ustawa 1989]. According to the regulations, land and buildings record is a uniform, systematized and updated collection of information on land, buildings and premises. With regard to land, the information contained in the land and building records concerns the location, boundaries of ownership, and surface areas, along with land use and soil quality classes. With regard to buildings, the register contains information on their location, utility function (whereas if the building performs several functions, the dominant function is revealed), as well as all the technical data on the given building, including: the year of construction and the material from which it was made. With regard to premises, the information contained in the register pertains to their location, function, and usable area. At this point, it is worth noting that a separate registration unit (entry in the records) is assigned only to those premises where the municipal governor (Polish: starosta), as the authority entrusted with the task of keeping the records, issued a relevant certificate. In the land and building records, information about the owners or usufructuaries is also disclosed, whereas the detailed scope of information to be contained in land and buildings records is defined in the Regulation [Rozporządzenie 2001].

In the Polish legal system [Rozporządzenie 2001, Rozporządzenie 2017, Ustawa 1964, Ustawa 1989], the boundaries of the right of ownership are defined as the area within which the owner can exercise his right in accordance with its socio-economic purpose [Litwin 2005], within the limits set by the laws and principles of social coexistence. According such formulation of the definition, which contains some degree of indeterminacy, it should be assumed that everything that is outside the area of the concept of spatial boundaries of real estate defined by the purpose of the land is not part of the land.

2. Types of cadastral system – an analysis of the literature on the subject

Although originally real estate cadastre only served for fiscal purposes and for property protection [Felcenloben 2009], it now has a wider application, following the dynamic development of information technology [Grand 2012]. Year after year, the cadastral system in Poland is approaching towards a multi-purpose cadastre, associated with real estate management, environmental protection, or the so-called sustainable development [Hernik and Noszczyk 2016, Taszakowski et al. 2017].

Progressive industrialization is another reason, which puts pressure on the changes in cadastral systems [Aien 2013]. It imposes the necessity of revising the presently existing solutions in the scope of two-dimensional cadastral land-plots (parcels) registration, which in some cases may prove to be insufficient. The record of plots in the format of spatial objects is already taking conducted in several countries with a high urbanization rate.

For the reason of various ways of defining a multidimensional cadastre, it is virtually impossible to create a uniform cadastral system with a global reach. For 3D cadastre, the International Association of Land Surveyors applies registration systems also in the area of underground structures, and infrastructure of utilities networks. To quote the source [Bydłosz 2012], one can distinguish five options for implementing a multidimensional cadastre:

1. The 3D Minimal Cadastre, which does not include infrastructural networks; also, it does not include roads or railways as 3D cadastral objects. Information about the premises is contained only in the form of layers, whereas three-dimensional objects are modelled by adding a symbol to the 2D map.
2. Topological 3D Cadastre, which does not create its own geometry for legal objects, whereas it defines objects by referring to physical boundaries of objects.
3. Polyhedral Legal 3D Cadastre, where plots are represented by polyhedrons having their own geometries.
4. Non-polyhedral Legal 3D Cadastre, which is similar to the previous one, however, it allows the possibility of defining surfaces with irregular shapes, for instance, cylindrical or spliced surfaces.
5. Topological Legal 3D Cadastre, in which the plots of land have a volume, and they are topological structures consisting of nodes and edges.

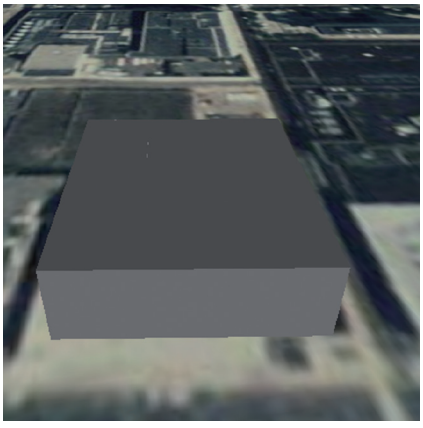
When it comes to a detailed list of features of individual models, it should be pointed out that each of the solutions used has both advantages and disadvantages, and the choice of the model should be adapted to the objective that we intend to achieve. One should also take into account the necessity of applying appropriate solutions in the field of implementation to models describing irregular surfaces, which can prove quite problematic. In turn, the use of the minimum model may bring unsatisfactory results in the context of the amount of work that must be put in to achieve the effect, also taking into account the need for legislative changes.

European Union countries are obliged to implement the INSPIRE directive [Dyrektywa 2007], according to which objects are defined as follows:

1) 2D data, where geometry of objects is represented in two-dimensional space,
2) 2.5D data, where the geometry of objects is represented in three-dimensional space, with the limitation that one value of the z coordinate is assigned to each point,
3) 3D data, where the geometry of objects is represented in a three-dimensional form, whereby there is no limit in the description with the X, Y, Z and data.

In the scope of buildings, the Directive provides for different levels of detail, using the so-called GML City [Rozporządzenie 2017, Shojaei 2014]. The individual levels are as follows:

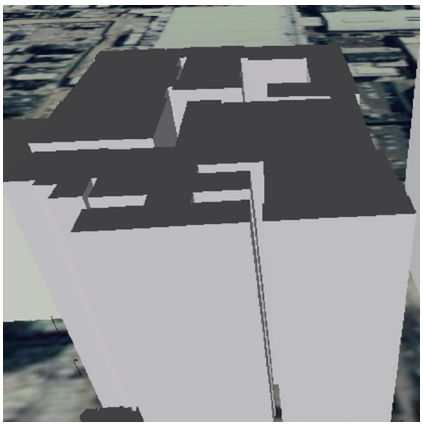
1. Level of Detail 1 (LoD1), where the building or its part is represented in a generalized way, as a straight prism with vertical walls and a flat roof (Figure 1).



Source: author's study

Fig. 1. Sample building depicted in LoD1

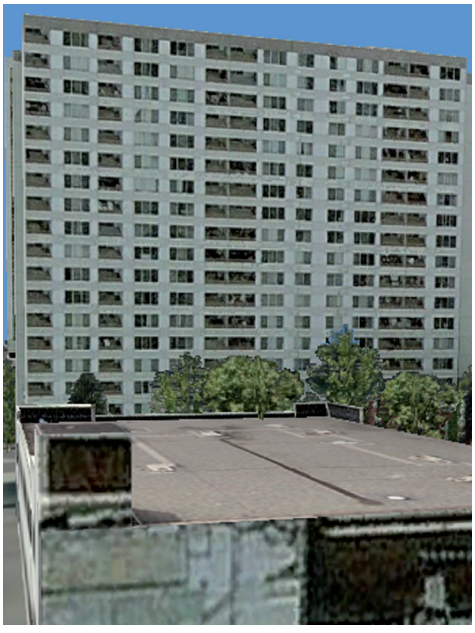
2. Level of Detail 2 (LoD2), where the building or its part is represented in a generalized way, wall surfaces are parts of vertical planes, and the roof is presented in a simplified form (Figure 2).



Source: author's study

Fig. 2. Sample building depicted in LoD2 with the shape of the roof shown

3. Level of Detail 3 (LoD3), where the building or its part is represented by the correct shape, limited by flat figures with a detailed description of the building's exterior, including the window and door openings (Figure 3).



Source: author's study

Fig. 3. Sample building depicted in LoD3, with windows and visible trees shown

4. Level of Detail 4 (Lod4), where the building's data from level 3 is supplemented with the data concerning the interior of the model (Figure 4).

Source: http://miasta3d.blox.pl/2009/05/CityGML-LoD-Level-of-Details.html

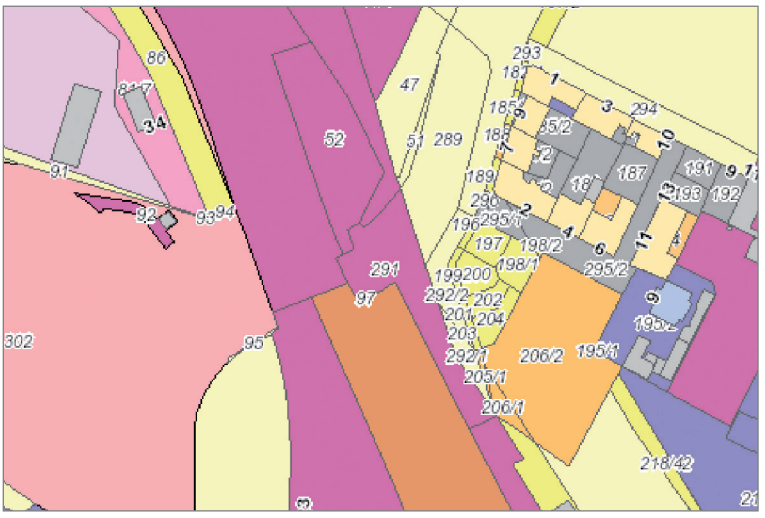
Fig. 4. Sample interior of a building depicted in LoD4

3. Multidimensional cadastre – report from the research so far

The city of Kraków is one of the largest cities in Poland, and it is still undergoing intensive development, therefore it is a good testing example for conducting an analysis of the legitimacy of introducing a multidimensional cadastre in selected cases.

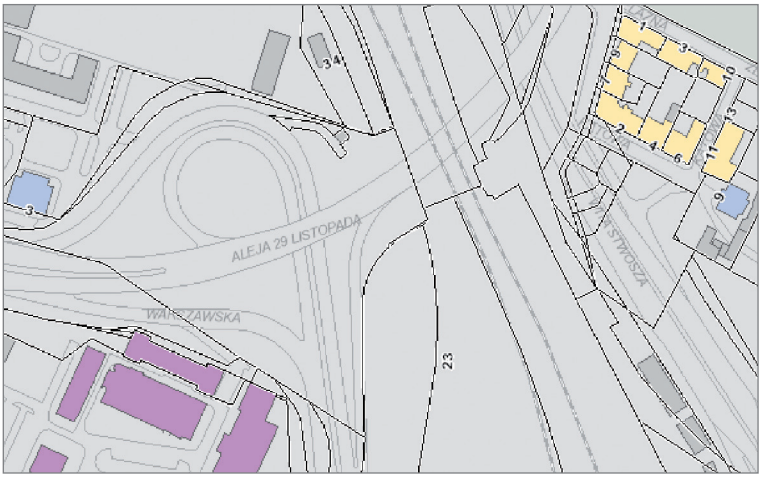
The case concerning the determination of the scope of property rights includes an overpass (a viaduct) located south of the Rakowicki Cemetery, and west of the Main Railway Station. The overpass is located above the road running from the station, but also above the railway line. As a result, the prepared map of the ownership structure (Figure 5) of the land in this location does not reflect the actual ownership status (Figure 6). Having said that, the railway plots are crossing the road plots in accordance with current regulations [Rozporządzenie 2017]. However, the situation – whether it is presented on the principal or on the cadastral map – is complicated by the existence of elements of the GESUT database. The elements of the database are featured under the viaduct, for example railway traction, as well as at the level of the viaduct, as evidenced by visible streetlights, among other things (Figure 7), which illuminate the streets after dark.

The railway plots of land are put into perpetual usufruct, while the road plots marked in yellow (plot 289) are in the possession of the Communication Board of the City of Kraków. The land ownership map presented here does not yet feature utilities infrastructure, which in this case is placed on several levels. A 3D cadastre, which will determine the exact extent of ownership, could be a helpful solution in this particular case. It will also help to define the exact course of the GESUT infrastructure, as well as facilitate any investment/renovation work.



Source: author's study based on the data from the Kraków City Council

Fig. 5. Map of the ownership of land plot in 29 Listopada street



Source: author's study based on the data from the Kraków City Council

Fig. 6. Contour map of land plots including elements of the BDOT database, showing 29 Listopada street

Another case concerns the building visible in the photo, located at the intersection of Zwierzyniecka and the Aleja Zygmunta Krasińskiego in Kraków (Figure 8). The main problem in this case is to determine the exact shape (Figure 9) as well as the function of the building.

Source: author's study

Fig. 7. Overpass at 29 Listopada street in Kraków

Source: www.google.pl

Fig. 8. Building at the intersection of Zwierzyniecka street and the Aleja Zygmunta Krasińskiego in Kraków

Source: author's study

Fig. 9. Building at the intersection of Zwierzyniecka street and the Aleja Zygmunta Krasińskiego in Kraków

The problem in determining the right of ownership is less important in this particular case, due to the location of the building within the plot, regardless of the course of the façade.

What is more important, is the method of determining the function of the building, and the number of storeys. The function has been defined as commercial. Legal regulations state that the function of a building, in the case when the building performs several functions, should be determined based on the dominant function. However, there are discrepancies in the legal provisions, regarding the definition of the concept of the dominant function of the building, as well as its definition in the case of many functions, whether it is a surface area criterion or a different one. Another case concerns the determination of the number of storeys, where regulations in this area have changed several times over the last 20 years, and where initially, the K-1 instruction [Instrukcja techniczna 1998] used to require filling in the number of the top storey, without providing the calculation method. Then, the regulation on land and building records of 2001 defined the attribute of the "number of storeys", not including the division into underground and overground storeys. Currently, the attribute of the "number of storeys" still poses problems, considering the incorrectly interpreted legal provisions [Rozporządzenie 2017] to which the regulation on land and building records refers.

4. Recapitulation

Maintaining a multi-dimensional land and buildings record should bring tangible benefits. Therefore, first of all, the operational land and building records should:

1) clear and simplest possible visualization and description of mutual spatial relations of various cadastral objects as well as legal status,
2) the ability to obtain information about errors resulting from the type of source data and the generalization of the object within the adopted cadastral model, which obviously has an impact on the correct interpretation.

The research we conducted using real data had demonstrated that for the creation of a multidimensional cadastre database, the existing EGiB, BDOT and GESUT databases will be useful when creating a 3D cadastre database, taking into account the current legislative solutions, or applying new ones, but with the existing attributes, which would facilitate a fairly easy implementation.

To recapitulate, it should be stated that there are rational reasons to introduce a 3D cadastre in Poland.

5. Conclusions

The current record of land plots in two-dimensional format may soon be insufficient, and it will be necessary to replace it with a different kind of record, taking into account the registration of spatial objects. It can therefore be assumed that in the following years, the development of technology will allow 3D visualization of the extent of spatial

rights assigned to real estate properties. The analysis of selected cases allowed us to formulate the following conclusions:

1. Due to the great practical significance of the records of the real estate property cadastre, the latter is subject to constant adjustments and changes. New models are emerging, resulting from legal and organizational conditions. The latter include also the society's needs in the ever-increasing accessibility of spatial data.
2. There are numerous models of cadastre as well as many methods of the application and implementation of those methods. It is impossible to create a uniform model of a 3D cadastre with a global reach.
3. To create a model of a multidimensional cadastre, in the Polish context, seems to be justified in some situations. Before introducing any changes that apply the solutions of the 3D cadastre, it would be necessary to first make a thorough analysis from the economic viewpoint, but also, and perhaps above all, from the social viewpoint. A radical change in the concept of cadastre management can do more harm than good. Thus, the 3D cadastre should be introduced on the principle of evolution, not revolution.

It should be noted that the way of keeping land and building records is important, whereas the lack of up-to-date data, the lack of interoperability of databases, or the lack of clearly defined guidelines for its operation causes the product itself to become unreliable, and therefore not valuable enough, or simply useless.

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