The New Methods of Visualisation of the Cadastral Data in Poland

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SUMMARY

Actually In Poland the cadastral system is a 2D based system. The system uses 2D parcels in order to register rights to the land, but according to the cadastral law 3 types of cadastral objects exist in the Polish cadastral system: land parcels, buildings and premises. Geometrical data concerning parcels and buildings are shown on cadastral maps. Nowadays visualisation of cadastral objects is becoming more sophisticated in cases of multiple use of space above a parcel and with more complex construction of the buildings.

Moreover, various untypical 3D objects located underground, like subway lines are not presented on cadastral maps. Additionally, the third object of the basic cadastral objects, i.e. premises – does not have its representation in the graphical part of the cadastre; its descriptive attributes are recorded in relation to a building. There is no geometric data, referred to premises in the cadastre and the relevant documentation, in the analogue form (views of premises i.e. Drawing of the Architectural and Building Inventory of Premises) exists only at Architectural and Building Offices (District Office). Views of premises are also attached to notary deeds of sale.

The paper presents the results of researches concerning the study of new ways of geovisualisation of cadastral data in Poland. Researches was performed at the Warsaw University of Technology, within the confines of the dean's research grant. The first part of the paper is focused on methods of visualisation of parcels in the cadastre i.e. visualisation of attributes of boundary points, status of boundary lines, visualisation of boundaries combined with data from other sources like the digital terrain model etc.

The second part presents the analysis of possibilities to develop models of premises for the needs of geovisualisation in the cadastre, basing on the existing architectural documentation, as well as the analysis concerning the adaptation of developed models of buildings' interiors to the needs of the cadastre. At this point technical issues related to the accuracy of projection of geometry of premises occur, along with the issues related to locating those models in the assumed coordinate system, with respect to x,y coordinates.

The third part presents the analysis of possibilities to develop models of subway tunnels for the needs of visualisation in the cadastre, basing on the existing surveying documentation i. e. laser scanning data of the interior of the tunnels and technical documentation of tunnels. It will not only allow to visualise the tunnel, but it will also be the first step towards registration of such objects in the cadastre using the layer approach (3D cadastre).

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1. INTRODUCTION

The current real estate cadastre in Poland is still based on conventional methods of data visualisation, i.e. on a cadastral map which projects spatial objects registered in the cadastre, such as parcels and buildings, in the conventional, 2D approach. It was designed in the past when other data distribution technologies and other user requirements concerning the data were applied.

It is important to adjust the standards of cadastral data visualisation obligatory in Poland (cadastral maps) to new, modern possibilities of information transfer and presentation and to the user requirements. It is also important to develop rules of geovisualisation for the needs of such cadastral objects in Poland which do not have their spatial representation in the cadastre. Such objects are premises which are registered (descriptive attributes) in the cadastre by means of relating them to buildings.

One of directions of research works concerns the development of an idea of the geovisualisation method in the case when the decision to develop the 3D cadastre is made. The cadastre in the world is facing the challenge concerning registration of objects which - by definition - were not cadastral objects in the past, but in the case when the 3D cadastre is introduced, it is also considered to register them in the cadastre. They include underground road, railway or subway tunnels and other underground structures which could be distinguished as independent, 3D real estates or which geometric features could become the basis for creating such spatial real estates. Therefore, registration of the geometry of such objects in three dimensions will allow for further modification of the approach to the cadastral registration, i.e. for introduction of the 3D cadastre which will allow for layer-approach to registration of property rights, in other words the division of the space of existing parcels in the vertical approach.

The authors of the paper discuss performed research works and some partial results related to presentation of cadastral data, in the context of the current solutions applied in Poland, which concern:
- modification of methods of data geo-visualisation concerning boundary lines and points,
- defining new cadastral maps combining vector and raster data (aerial photographs) and the terrain relief model,
- geo-visualisation of data concerning premises,
- geo-visualisation of data concerning untypical objects n the cadastre – e.g. subway tunnels.

2. GEO – VISUALISATION OF PARCELS IN THE CADASTER

Cadastral maps differ in many countries in relation to the presented content. Basing on the comparison of the content of cadastral maps, performed by Karabin (2012) for such countries like: Austria, Finland, the Netherlands, Lithuania, Germany (North Rhine-Westphalia), Sweden and Poland – the high diversification of cadastral maps content may be noticed, from maps containing data on parcels (boundaries, parcel numbers) and land use types, to maps with the enhanced content concerning data from local spatial management plans.

In the authors' opinion it was reasonable to analyse cadastral maps with respect to presentation of the status of the establishment of locations of boundary points and the status of a boundary line. Basing on information acquired from the site www.cadastraltemplate.org authors analysed the content of cadastral maps from Argentina, Australia, Austria, China, Ethiopia, Japan, Poland, the Republic of South Africa, South Korea, Sweden, the Germany (the Free State of Thuringia), Norway.

The status of the boundary point is presented on Austrian and German (Free State of Thuringia) cadastral maps only, with the description "settled" or "unsettled". In Austria a parcel may be additionally enlisted in the, so-called “boundary cadastre”, if all of its boundaries were established using appropriate surveying-and-legal procedures, following the presentation of the boundary points in the field with the presence of the parties and when the parties approved it by signing the relevant protocol. Any analysed country does not have a cadastral map on which the status of a single section of a boundary lines is presented, i.e. information whether its position had been settled or not.

The boundary point is defined in Poland by the following attributes: STB – the stabilisation code, ZRD – source of data on the location of the boundary points, BPP – the mean error of the boundary point in relation to the 1st class control points network.

The Polish cadastral maps also present the status of the boundary point, but to the limited extent. Diversification in the cartographic space concerns the attribute of the point stabilisation (stable/unstable) only; however diversification related to the attribute which characterises the accuracy of the location of a boundary point does not occur.

Figure 1 on the map to the left – all points are presented in the same way, since permanent stabilisation of points was not performed, however the status of points is different in relation to the accuracy of their location, i.e. the value of the BPP attribute. The analysis of the source cadastral documentation (documentation of division of a real property including the parcel no. 127 – resulting parcels 127/10, 127/11, 127/12 and the parcel 96 – resulting parcels 96/1, 96/2, 96/3) and the BPP attributes allows to distinguish boundaries settles by geodetic procedures and boundary points o the BPP values from the interval 0.00-0.30m. Figure 1 on the map to the right such sections of boundaries are marked in black and the points are marked as circles and letters from A to M; other boundaries on the cadastral maps which originate from vectorisation of a raster analogue map were marked in red.

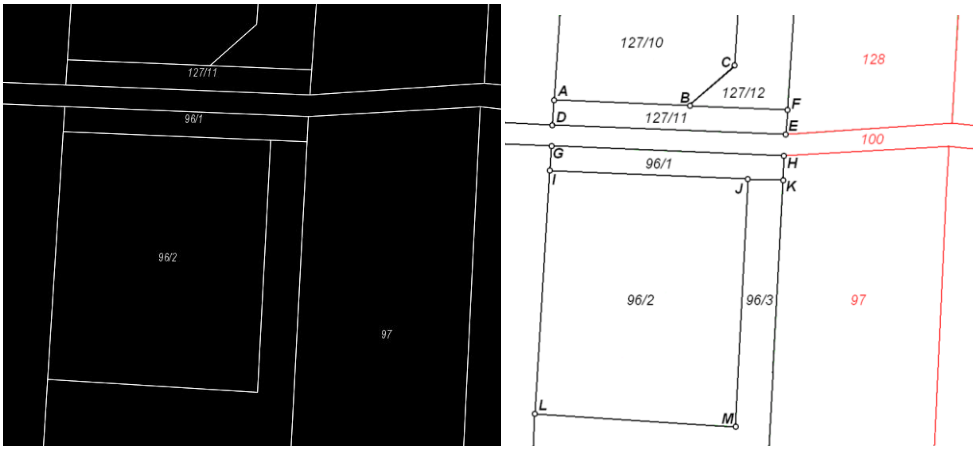

Fig.1 Cadastral map – issues related to the attributes of the boundary points and lines
Source: own research works

Conceptual works related to disclosing such information on cadastral maps were performed by Łuczyński (2016). He distinguished boundary lines into such lines which location was settled (i.e. restored basing on archival data, including calculation of coordinates of boundary points in the assumed coordinate system) and such boundary lines which location was unsettled; he additionally proposed to mark points which support the boundaries in a different way than the points which were presented in the field by protocols and those which were not presented in the field.

The authors propose to extend the cartographic presentation related to attributes and the status of boundary points and lines in such a way that they would precisely determine whether the given boundary section had been settled and presented in the field and whether the relevant administrative decision had been issued and whether all parties had approved their locations in the field.

3. THE CADASTRAL HYBRID MAP

The conventional method of representation of cadastral data on a map consists of two-dimensional visualisation of cadastral parcels, usually performed as black, unfilled outlines (boundary lines). It is the typical visualisation of vector data.

A map in such a form does not allow to achieve the "added value" resulting from visual interpretation of superimposition of cadastral data and information originating from other registries and spatial databases. Examples of the different approach are innovative proposals of hybrid cadastral maps which combine vector data and raster data (aerial photographs – ortophotomaps) and the three-dimensional digital terrain model (DTM).

The objective is to present cadastral parcels data as the three-dimensional cartographic presentation and the superimposition of the cadastral content on the orthophotogram of the sufficient spatial resolution (Fig. 2). Interesting and useful results may be achieved by superimposing the cadastral content on the derivative DTM products, such as the maps of slopes (Fig. 4) and the hypsometric map (Fig. 5).

Fig. 2. Semitransparent map of slopes imposed on orthophotomap and cadastral data
Source: own research works

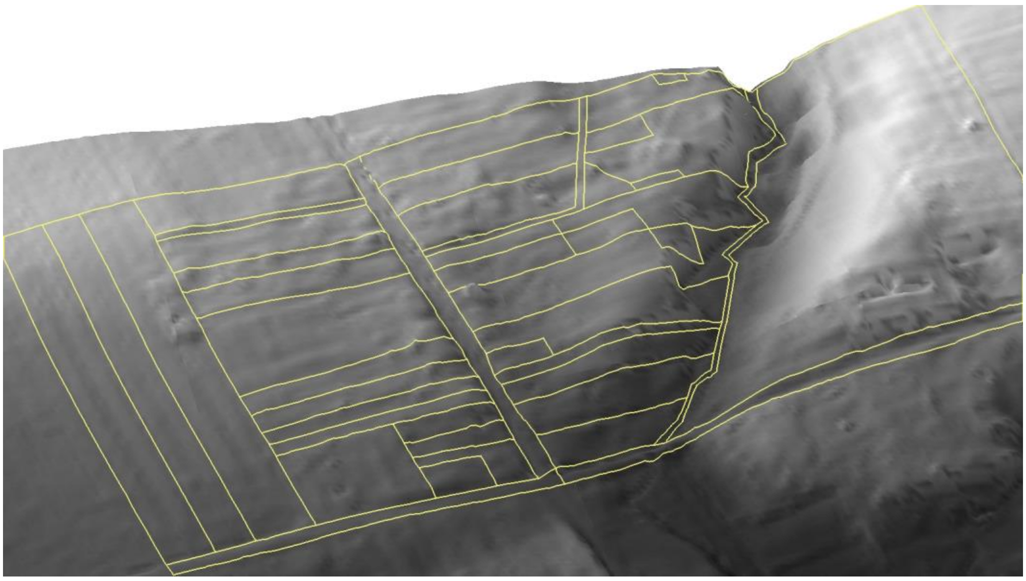

Fig. 3. Cadastral data on the background of DTM
Source: own research works

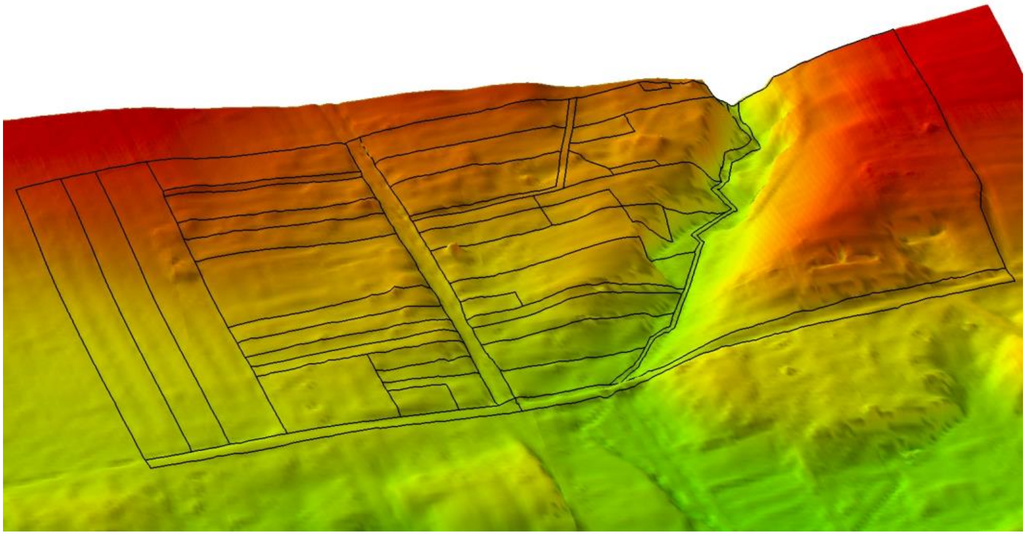

Fig. 4 Semitransparent map of slopes imposed on DTM with colour-coded elevation (combined with cadastral data)
Source: own research works

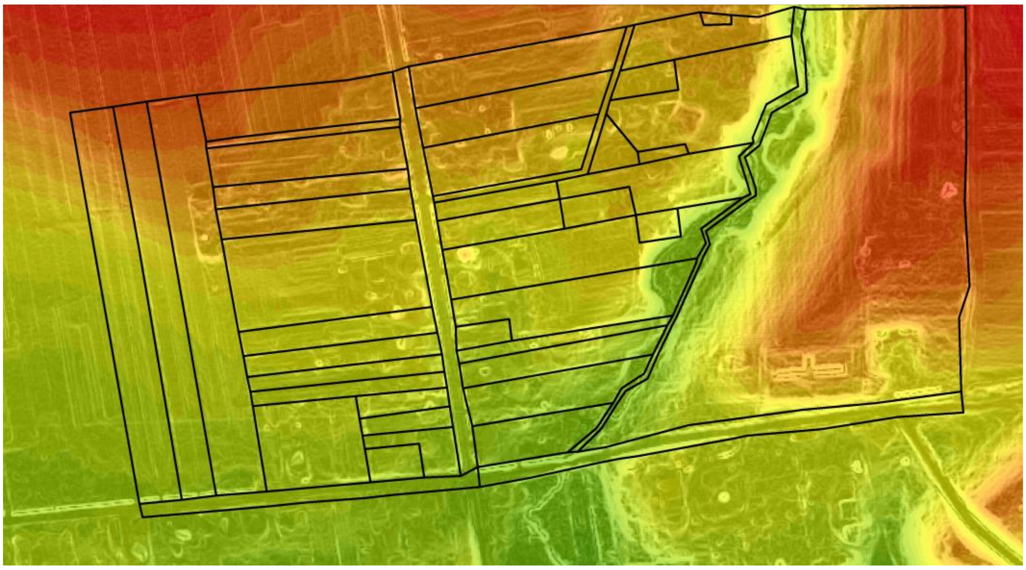

Fig. 5 Cadastral data on the background of hypsometric map
Source: own research works

Superposition of such products allows for increasing the perception of users. It can be particularly well visible in the case of high elevation differences and high values of the terrain inclination.

It is worth to consider that integration of topographic data (the cadastre, ortophotomaps) and elevation data (the digital terrain model and derivative products) allows not only for the visual assessment of land use methods of a parcel (orthophotomaps) or the terrain relied (DTM). The use of geoinformation technologies also enables the quantitative analysis of integrated data in the three-dimensional space. An example may be the comparison of sizes of cadastral parcels determined by means of cartometric 2D and 3D analyses.

The differences are even more important when geomorphological diversification of the terrain is higher. However, it should be stressed that the obtained results will be highly influenced by the geometric accuracy of source elevation data. The precise digital terrain model used in research works was developed basing on results of the airborne laser scanning with the average density of 4 points per sq. m (Kurczyński i Bakula, 2013). Such DTM have the relevant accuracy for the analysis of cadastral data.

4. GEOVISUALISATION OF PERMISES IN THE CADASTER

Geometric data concerning the premises are stored in two places in Poland, i.e. at the District Office (the Department of Architecture) which issues certificates about independence of premises and at the Local Court, at the Section of Land Register, as the annex to the notary act concerning given premises. In both places data is stored as analogue documents.

This documentation includes architectural projections of particular floors of a building; in the case when spaces attached to premises (garages, cellars etc.) are located outside the apartment building they are also marked on the copy of the cadastral map. The above documents are the annexes to the certificate which states that the requirements concerning the independence of premises are met and they are also the annex to the notary deed, establishing a separate ownership of premises. The real property cadastre contains only descriptive data concerning the premises.

As it was stated by Karabin (2014), attempts to perform three-dimensional visualisation of premises were undertaken in many countries. For example development of 3D models were based in Spain on information about the number of storeys from the cadastral map and on the assumption of the storey average height (3m in Spain) (the, so-called, *3D Model General Floor*) or on the use of projections of premises (if they are available) and data extracted from those projections (the, so-called, *3D Model By Floors*). Similar solutions may be found in Malaysia.

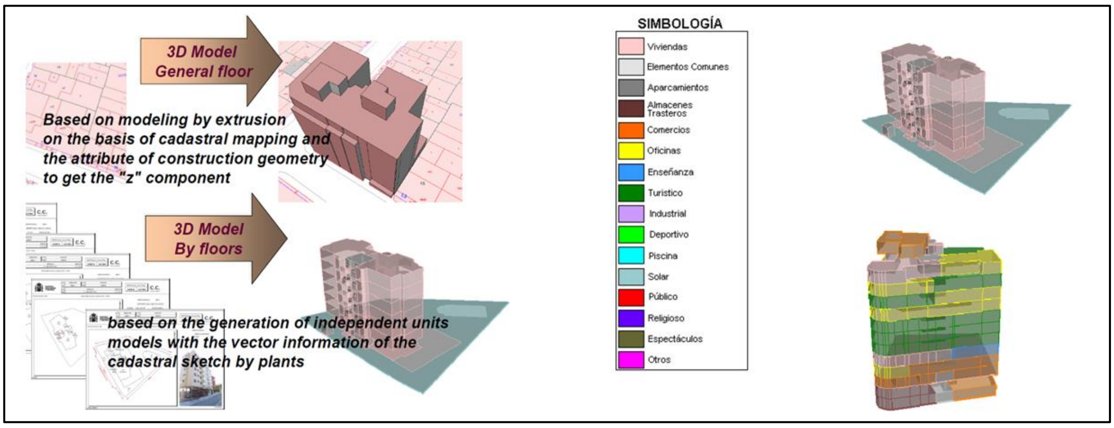

Fig. 6. 3D visualisation of buildings and premises in the Spanish cadastre
Source: García et al. (2011)

In many cases visualisation of premises in cadastral systems aims at improvements in real property management processes and simplification for external users of locating such objects in the space of groups of premises in a building. Such visualisation is performed even if the geometric accuracy of registration of such objects is deteriorated (models developed on the basis of architectural projections of premises with the assumption of the average heights of premises) (see Karabin, 2016).

Chiang (2012) presents results which may be achieved in the cadastre in Taiwan, where pilot applications were implemented which resulted in possibilities to visualise buildings and premises in 3D.

Architectural projections of premises may be also registered in the form of scanned documents in cadastral systems of such countries as the Netherlands, Lithuania, Croatia.

The authors performed experimental works. The following general assumptions were made, concerning the extension of the content of future Polish cadastral maps by information concerning premises:

- It should be possible to present the geometry of premises in a unified coordinate system together with other cadastral data and to develop the correct cartographic visualisation.
- The developed model should be an element of a building data model, utilised for different purposes: management of a building, crisis management, indoor navigation systems, the real estate cadastre.
- It is proposed to enter data at least at two accuracy levels: with representation of whole premises and with representation of rooms.

One of research tasks was to determine the way of modelling boundary lines of premises and rooms in order to ensure the possibility to perform correct spatial analyses and, on the other side, the high geovisualisation quality. Two concepts were developed:

- The boundary line of premises (which is the outer wall) is drawn along its external edge (at the floor level). Lines being boundaries between two premises are drawn on the axis of the separating wall.
- Boundary lines of rooms are drawn on internal edges of wall at the floor level.
- Rooms are separated into sub-spaces due to the different method of calculation of the useful space (in Poland another coefficient is applied for calculated room sizes for the room height above 2.20 m (100%), the height between 1.40m and 2.20m (50%) and for some rooms of the heights lower than 1.40m (0% - not considered in calculations).
- Data is acquired and recorded in the coordinate system applied in the given cadastral system (in order to achieve the full compliance with data for the building surrounding areas).

Below an example of visualisation of rooms is presented. They are rooms occupied by different users at the Main Building of the Warsaw University of Technology. Premises being separate properties may be presented in the same way.

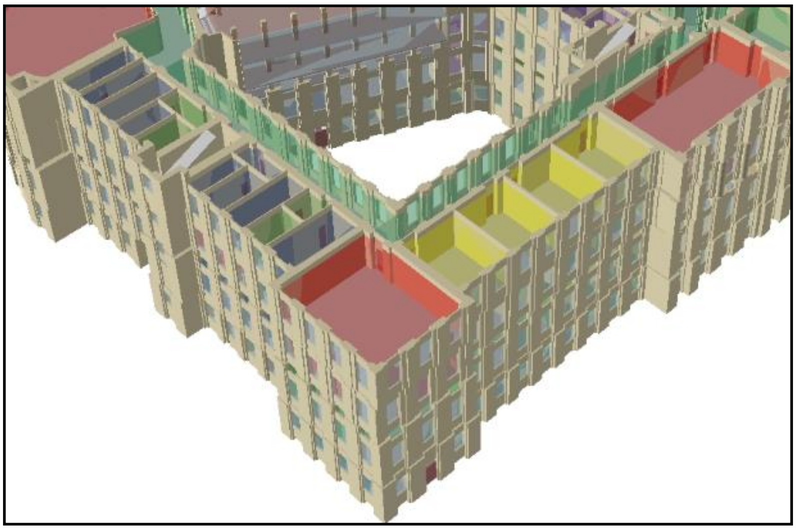

Fig. 7 Visualisation of rooms. Main Building of the Warsaw University of Technology.
Source: own research work

However, the main issue of research works is to determine, how to present all cadastral data in a coherent way. The 3D-Tags solutions seems to be the most appropriate; however they require modifications of the conventional cadastral map in order to mark information on separate premises in a building on that map.

The simplest solution is to mark buildings with separate premises with another cartographic symbol (e.g. by introducing patterns) and introduce a reference label with a number of a file which presents the model of a building interior (divided into rooms). The model should be displayed by pointing (with a mouse cursor) to the outline of such a building and directing the user to software which supports 3D visualisation of the building.

5. VISUALISATION OF UNTYPICAL OBJECTS IN THE CADASTER

Issues related to the registration of subway data were already considered in some foreign and Polish publications: Ploeger, Stoter (2004), Rönnberg, Hedmark (2010), Karabin (2011), Matuk (2015).

As it was stated in (Karabin, 2011) in the context of the subway in Poland - the only information accessible in the cadastre refers to subway stations, which have the nature of buildings, as well as about accompanying technical buildings related to aeration of the tunnel etc. What refers to the tunnel itself and its location – such information may be found on the base map only and in the technical documentation of Metro Warszawskie Ltd. company.

It is related with the fact that – according to the regulation of the Ministry of Administration and Digitisation dated October 21, 2015 on the district and the national Geodetic Database of the Technical Facilities (GESUT) – the subway tunnels are the objects of the GESUT database and they are presented on base maps only.

Below fragments of the cadastral and the base maps are presented on which the subway tunnel (in red) and another, similar underground object – the city tunnel of trains (in yellow) may be identified.

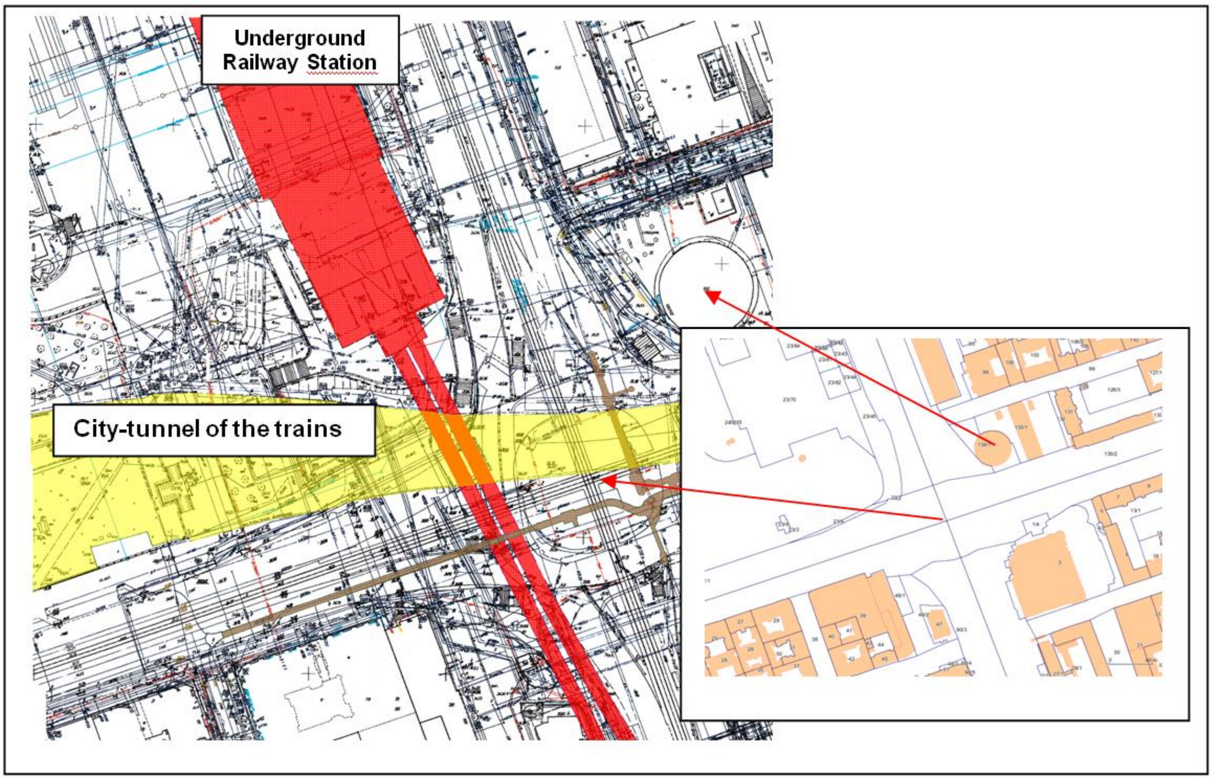

Fig. 8. Subway data on a cadastral and base map
Source: The Office of Geodesy and Cadastre for the City of Warsaw – published in Karabin (2011)

As the subway tunnel has its representation on the base map only in the form of projections of tunnel edges, bodies created the tunnel were created in three dimensions within the experiment. Basing on data from terrestrial laser scanning of inside of two subway tunnels section (data received from Metro Warszawskie Ltd. Company), 970 sections generated every 1 m were provided as a source for geometric model of subway tunnels. During processing of this dataset, a generalization process has been carried out. The course of the tunnels was defined as a middle of profile and then 3D buffer function allowed to create 3D solid representation of the tunnels. The maximum deviations with respect to profile points were less than ± 0.015m for the right tunnel and ± 0,009m for left, which is sufficient accuracy for the visualization in cadastral studies.

Data describing subway tunnels were connected with airborne laser scanning (ALS) data acquired in April 2012. Airborne scanning data are characterised for urban areas by the density of 12 points per sq.m. (Kurczyński i Bakula, 2013). The digital terrain model and the digital surface model were developed basing on these data with a spatial resolution of 0.5 m. Then they were visualised as the shaded model. Geovisualisation was performed in GIS environment. The 3D city model presented below was also developed with ALS data using classified point cloud, particularly "buildings" class. It represents the level of details of the CityGML standards, at the LoD2 level, with the level of details of 0.5m maintained.

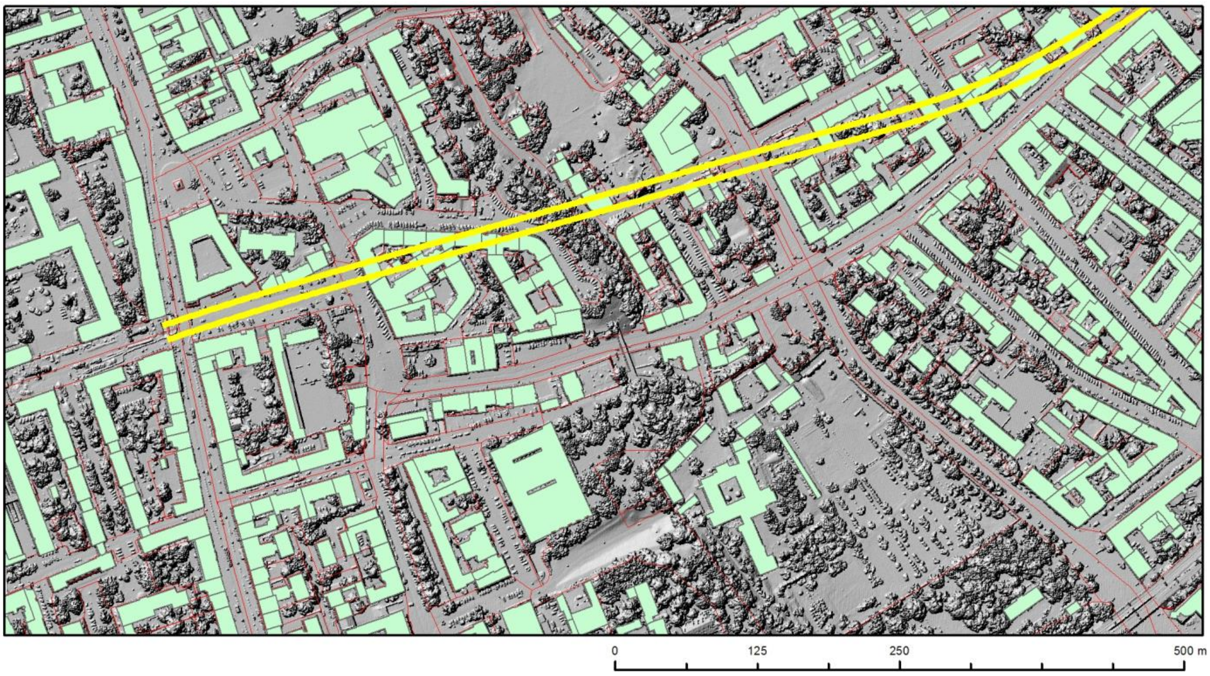

Fig. 9. The digital surface model (hillshade shaded) with the subway tunnel (in yellow) superimposed and with visible boundaries of cadastral parcels (in red) and outlines of buildings (green polygons). Source: based on data received from Metro Warszawskie Ltd. Company and ALS data – own research works

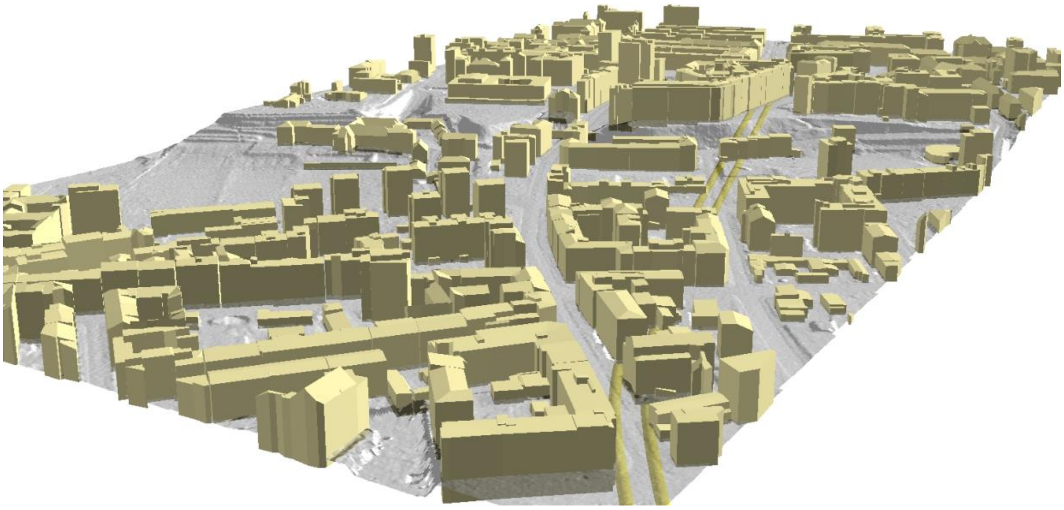

Fig. 10. The perspective view of the 3D city model of Warsaw at the LoD2 level of details, with the visible subway tunnel under the terrain surface. Source: based on data received from Metro Warszawskie Ltd. Company and ALS data – own research works

Such integration of data allows not only to visualise subway data, but – if the 3D cadastre is to be developed – also to create required cross sections and spatial 3D parcels covering the subway tunnel and spatial buffers around them.

6. CONCLUSIONS

The paper presents the results of first experiments and attempts related to development of new way of visualisation of cadastral data. At this stage the authors have not assessed issues related to practical implementation. However, basing on performed experiments it may be stated that the cadastral map in two-dimensional form should be considered in the future as one of many possible forms of geovisualisations. The conventional map used for visualisation purposes will be probably substituted by the 3D model.

Nevertheless, it is worth to work on new ways of 2D-geovisualization and standardisation of this kind of cartographic presentations developed using multi-source 3D data (photogrammetry, remote sensing, underground surveying). As it was proved by first experiments, considerably high possibilities exist in this field.

Even when the 3D cadastre does not exist, new visualisation opportunities should be developed. Hybrid cadastral maps, mentioned above, may be very useful. Also conventional, simple vector drawings presenting parcels, buildings and lands may be substituted by colourful drawings with modern labels and complex cartographic symbols. Technical limitations in this field do not exist and the cadastral content may be presented in the more effective and attractive way.

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BIOGRAPHICAL NOTES

Marcin Karabin Ph.D., D.Sc. Born in Warsaw in 1976. Studies of Geodesy and Cartography at the Warsaw University of Technology. Graduated his (M.Sc.) in Geodesy in 2000. Obtained his Ph.D.

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Robert Olszewski deals with the modeling of spatial information, extraction and acquisition of spatial information using artificial intelligence methods, as well as the subject of smart city, cartographic generalization, geostatistics, gamification and social geoparticipation. The results of many years of his scientific work have been published in several monographs and more than one hundred articles. Since 2011 a Professor at the Warsaw University of Technology (Department of Cartography), since 2015 Head of the Department of Cartography. He works with business and government and self-government in the implementation of R&D projects and commercialization of interdisciplinary research in the field of geoinformation, computational intelligence, spatial data services, social geoparticipation, gamification, smart city, and spatial data mining.

Dariusz Gotlib Ph.D., D.Sc. Graduate of Geodesy and Cartography at the Warsaw University of Technology (1995). Full-time research worker and lecturer at the Warsaw University of Technology since 2001. Cartographer and GIS expert. Directly involved in design and implementation of the Spatial Data Infrastructure in Poland. Since 2001, the leader of teams specializing in the design and maintenance of spatial databases for navigation systems and modeling of topographical data. More than 10 years of experience in managing the work of GIS department and GIS Database Operation department in polish commercial companies. Current position: Associate Professor at Warsaw University of Technology (Department of Cartography, Faculty of Geodesy and Cartography).

Anna Fijałkowska obtained Master of Science degree in 2001 at the Department of Geodesy and Cartography, Warsaw University of Technology (in the field of photogrammetry and remote sensing). Participant of the scholarship program of the French Government (BDF) in 2002. She obtained a Master's degree Diplôme d'études supérieures spécialisées (DESS), University of Paris VI (remote sensing field of study) and undertook PhD studies at the, Warsaw University of Technology. Since 2006 she has been employed in the Department of Photogrammetry, Remote Sensing and Spatial Information Systems. She was involved in several projects financed by KBN and Ministry of Science and Higher Education in the field of remote sensing, design and implementation of GIS and spatial databases. She is the author of many publications related to the design and use of GIS, multi-criteria spatial analysis, GIS technology, network analysis, processing of DTM and the use of 3D data and 3D analysis, as well as in the field of remote sensing. She has the ability in Python programming language to extend the functionality of ArcGIS and QGIS applications.

Krzysztof Bakuła Ph.D., Obtained his Ph.D. in 2015 and his M.Sc. in 2010 both at the Faculty of Geodesy and Cartography, Warsaw University of Technology. Photogrammetrist and Remote Sensing Expert, author of over thirty scientific publications related mainly to the analysis and the application of multi-sourced photogrammetric and remote sensing data. Member of International Society for Photogrammetry and Remote Sensing (ISPRS officer), The International Committee for Architectural Photogrammetry (CIPA member), Polish Society for Photogrammetry and Remote Sensing (Secretary). Current position: Assistant Professor at Warsaw University of Technology (Department of Photogrammetry, Remote Sensing and Spatial Information Systems, Faculty of Geodesy and Cartography).

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