Layer approach to ownership in 3D cadastre – a subway case

Marcin KARABIN, Poland, Dimitrios KITSAKIS, Greece, Mila KOEVA, Netherlands, Gerhard NAVRATIL, Austria, Jesper PAASCH and Jenny PAULSSON, Sweden, Nikola VUČIĆ, Croatia, Karel JANEČKA, Czech Republic and Anka LISEC, Slovenia

Key words: 3D cadastre, subway tunnels, layer approach

SUMMARY

The paper focuses on approaches to the registration of real property rights in the case of underground or subway tunnels in different EU countries: Austria, Bulgaria, Czech Republic, Croatia, Greece, Poland, Slovenia, and Sweden. The Authors made analysis of the current way of registration of rights to subway tunnels in the chosen countries, including its effectiveness in ensuring appropriate property rights to construct and exploit tunnels. A special attention was given to limitations related to the lack of the possibility to vertically divide the space, i.e. to divide the space into layers, and to refer the ownership right to the layers.

Benefits which might be achieved by the introduction of a 3D real property cadastre were pointed out. The analysis of available data concerning the geometry of subway tunnels in particular countries was presented. The authors tried to answer the question whether the accessible data concerning the geometry of subway tunnels allows to generate a 3D geospatial model of a constructed object, and to specify the space which should be determined as a 3D parcel in the 3D real property cadastre, for the purpose of registering property rights for the object (the tunnel).

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1. INTRODUCTION

At present, implementation of public transport investments (such as subway, railway lines in tunnels and on viaducts, roads on viaducts etc.) are performed in the, so-called, "layer" system. This means that an infrastructure object, such as tunnel or bridge, is often allocated over or under a “traditional” 2D land parcel. Consequently, infrastructure objects are planned and realised at various levels (layers) within the space of a given land parcel. Several parties may be interested in development of particular fragments of the parcel space; each of them is interested in purchasing rights only to a specified part of the parcel (its specified layer) where a given investment is implemented by that party. Legal conditions binding in many countries do not allow for implementation of subway type investments within the space of a someone else's cadastral parcels, based on the ownership right. The reason is the "superficies solo cedit" principle, which is binding in many EU countries - the ownership right extends above and below the land parcel defined on the Earth’s surface and cadastral systems do not allow to vertically divide a real property (Stoter, 2004; Paulsson, 2007).

The conventional land administration system based on 2D cadastre, which does not allow for vertical division of the parcel space, forces an investor to purchase an entire parcel or to get other rights, which allows to use a specified space of someone else's parcel, such as servitude rights. Implementation of such investments in cities, accompanied by purchasing entire parcels, generates additional costs; implementation of investments only below the land surface that are municipally or state owned without purchasing properties of other parties may lead to not optimal location of a tunnel. The fact that there is no option for vertical division of a land parcel results in practically impossible transactions of parcels, where infrastructure objects are allocated, even in the cases of subway tunnels. Namely, following the "superficies solo cedit" principle - an underground infrastructure object, as an example, is a component of the land parcel, the real property. Consequently, the urban space is not optimally utilised.

The servitude right has some disadvantages since it cannot be encumbered with a mortgage, therefore it is not the basis to credit a given investment. The 3D cadastre allows to delineate 3D parcels (from the space of existing 2D parcels) that cover specified fragments of the space and to relate ownership rights to those delineated fragments. Within a 3D Cadastre system such objects can be registered as separate cadastral objects. This allows for implementation of a line investment in the underground space in a flexible way, i.e. it is possible to get financing of an investment based on the mortgage charge of a 3D property and market transactions of the remaining space after delineation of the 3D parcel, covering the subway.

In the paper, the approaches to the registration of real property rights in the case of underground subway tunnels in different EU countries are presented. Research works are performed using examples of subway tunnels constructed in authors countries: Austria,

Bulgaria, Czech Republic, Croatia, Greece, Poland, Slovenia, and Sweden. In some countries (Sweden) it is possible to distinguish 3D real properties.
The authors analysed the current way of registration of rights to subway tunnels in the chosen countries, including its effectiveness in ensuring appropriate property rights to construct and exploit tunnels. A special attention was given to limitations related to the lack of the possibility to vertically divide the space, i.e. to divide the space into layers, and to refer the ownership right to the layers.
Benefits which might be achieved by the introduction of a 3D real property cadastre are furthermore pointed out. We tried to answer the question how the owner of a “traditional” 2D land parcel may claim for the ownership or use right to a part of the parcel, where a construction of a subway tunnel is planned.
As a separate part, the analysis of available data concerning the geometry of subway tunnels in particular countries is presented. The authors tried to answer the question whether the accessible data concerning the geometry of subway tunnels allows to generate a 3D geospatial model of a constructed object, and to specify the space which should be determined as a 3D parcel in the 3D real property cadastre, for the purpose of registering property rights for the object (the tunnel).
Therefore both, legal and technical aspects related to the modification of the approach to registration of the rights to the subway within the frames of implementation and operational use of a 3D real property cadastre will be discussed.

2. "SUPERFICIES SOLO CEDIT" PRINCIPLE AND “LAYER APPROACH” TO OWNERSHIP IN 3D CADASTRE

Modern urban environment is characterised by the development of horizontally overlapping constructions, of various land use, extending on multiple height levels, by various stakeholders. In terms of land tenure, a statutory establishment of such types of overlapping developments does not comply with the principle of “superficies solo cedit” (right of accession). The “superficies solo cedit” principle dates back to the Roman law and is one of the fundamental principles of Land Law, both in Civil and Common Law jurisdictions. According to its stipulation, ownership of land encompasses all developments constructed on it. Consequently, in case of constructions at various height levels, for various purposes and by various stakeholders, the right of ownership is to be assigned to the owner of the land-surface parcel. Similar limitations need to be faced also for the registration of the real property rights related to each of the multilevel developments.
However, doctrinal principles cannot inhibit the practical necessities of everyday life, especially in case of accommodation purposes (van der Merwe, 2010). Within this concept, stipulations regarding the extent and the content of real property were included in Civil Codes, aiming to leave room for real property stratification and to distinguish accession of movables and fixtures to immovable real property. This is also related to the Roman maxim “cujus est solum ed usque ad coelum et ad inferos” that describes the vertical extent of real property from the centre of the Earth to infinity. Civil Code stipulations provide characteristic examples both of the former, such as restriction of the vertical extent of real property ownership “to the height and depth that the owner has no interest in opposing against it” or

similar stipulations (e.g. German Civil Code, Art. 903; Greek Civil Code, art. 1001), and of the latter, e.g. regulations regarding component parts and accessories of real property. In addition to Civil Code stipulations, specific legislation has been introduced in many countries, in the form of condominium, horizontal property, apartment or strata legislation allowing vertical segmentation of a real property to individually owned real property units, mainly serving residential purposes. However, different types of use may also be allowed. For example, Uniform Common Interest Ownership Act (2008) of the United States provides that condominiums may consist of unenclosed ground or airspace while, depending on jurisdiction, condominium can be used for commercial purposes, parking, caravan site, street market, mooring space (“dockominiums”), or even graveyard condominiums can be established (van der Merwe, 2015; van der Merwe, 2016).

More complexities arises in case of underground infrastructure objects due to their cross-boundary characteristics. Circumventing of the “superficies solo cedit” principle is achieved by constructing underground infrastructures to such depth that surface parcel owners have no interest to exploit, thus no harm or loss to their surface property is considered to be caused. Specific minimum depth of disposal of underground land are not very common in national legislation. For example, in Malaysia, minimum depth of underground space disposal ranges from 6 to 15 metres, depending on surface parcel land use (Zaini et al., 2013); in the state of Victoria in Australia, alienation of Crown land is allowed only up to the depth defined by the Governor in Council, while in Finland underground land can be freely utilised up to the depth of 6 metres (Vähäaho, 2014). The difference of the Finnish case is that the surface parcel owner owns the underground of his parcel, despite the depth limitation, but does not have the right to use it for construction purposes deeper than 6 metres without permit (Vähäaho, 2014). Despite practical addressing of the problem by developing underground infrastructures to depth that surface parcel owners have no practical interest to oppose, when the exploitation of a real property over a public utility needs to expand at a new, greater depth, complications arise, resulting either to the cancellation of the planned exploitation or to the expropriation of the surface parcel (Kitsakis and Dimopoulou, 2017). Depending on jurisdiction, this may imply that, although surface parcel owners cannot exploit their surface parcel to its full extent, there is no compensation provided for the restrictions imposed on the exploitation of the surface parcel’s depth (Kitsakis and Dimopoulou, 2017)

The idea of the "layer" approach to the rights and their spatial ranges, registered in the cadastre has been presented in Dimopoulou and Elia (2012). The necessity to define the range of property rights necessary for implementing of "layer" approach was stressed, among others, by Acharya (2011), Dimopoulou and Elia (2012), Erba and Graciani (2011). Dimopoulou and Elia (2012) presented such a division of space of the traditional cadastral parcel (Figure 1).

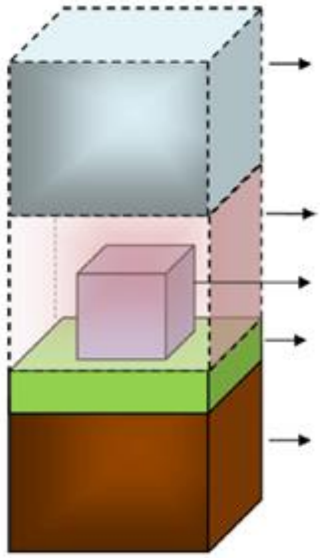


Figure 1. 3D legal and spatial ownership right clarification, Source: Dimopoulou and Elia (2012)

As a result the space will be divided into the space accessible by the owner, and the space, which will be reserved for the State or Local Authority. Karabin (2013) proposed a small modification and considered the necessity of registration of the space owned by the State which will never be a subject of private ownership (for example space necessary for assurance of the air traffic, space where natural resources occur, below the depth accessible by the private entity). It will allow for introduction of 3D cadastral properties and also for implementation of the 3D cadastre.

3. REGISTRATION OF SUBWAY AND UNDERGROUND TUNNELS IN EU COUNTRIES

3.1 Subway in Austria

Vienna is the only Austrian city with a subway network. The construction started in 1969 and the first section was opened in 1976. Although the tunnels mainly follow public roads, parts of the tunnels intersect private property. Since the Austrian cadastre is based on 2D-representation of land parcels, it was not possible to register the tunnels as a separate property. Easements have to be registered in the land register in order to protect the rights of both parties, the landowner and the subway authority. Negotiations with the landowners on compensations start during the project planning and contracts on this matter are signed before constructions start but the final easement documents are established after finishing the construction. This prevents the need to change easement documents if small changes in the original planning are necessary.

The easement document consists of a text document describing easement in detail and the compensation paid for it and a graphical appendix defining the spatial extent. Figure 2 shows a section of the appendix for a current project, the extension of the line U6. The left part is a

2D representation containing cadastre (green), situation and objects at the surface (black), and the extent of the easement (yellow with red lines). The vertical extent is shown as a cross-section on the right side. Heights are based on “Wiener Null”, the reference height for official surveys in Vienna (152.68m based on level Trieste). The protected volume exceeds the space of the subway in order to prevent damage to the subway by future construction work.

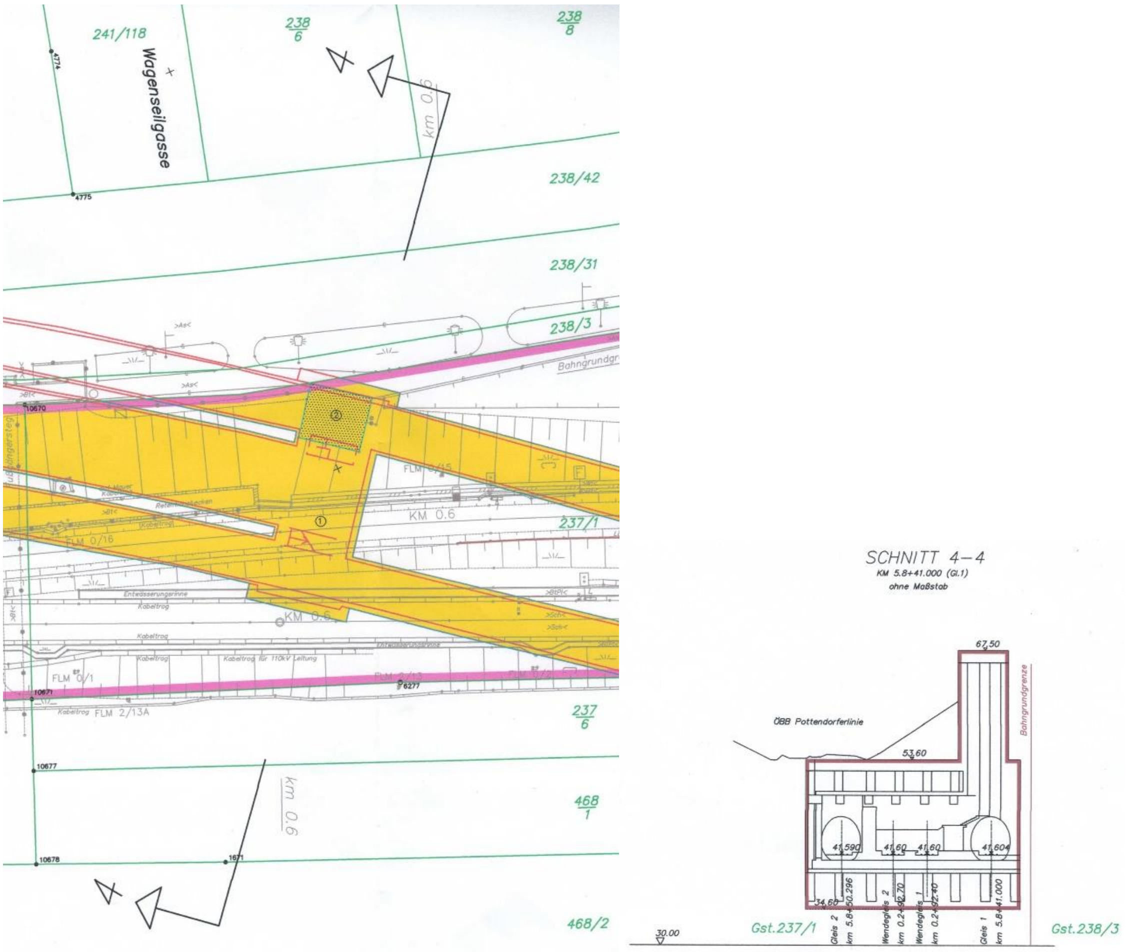


Figure 2. Details from easement plan for the subway line U6 (data: Korschineck & Partner Vermessung ZT-GmbH)

Although the subway network is perfectly documented in Vienna, it is not shown on cadastral maps. The lines do not necessarily follow parcel boundaries. Easement boundaries are not included in the cadastral maps and thus the extent of the easements is only evident from the documents in the land register. They are currently only accessible in digital form back to 2006, older documents are only available in analogue form.

3.2 Subway in Bulgaria

Sofia Metro is an underground railway network in Sofia, capital of Bulgaria. The capital is the largest city of Bulgaria and the 12th-highest populated cities in Europe. Its population is 1.4 million. The increased population of Sofia forced the construction of the metro system.

Planning of the metro started in the 1960s and was executed for the first time in 1990s. It was planned to provide quick and safe transport to the citizens. Bulgarian Metropolitan-Sofia JSC is the operator of the metro system (https://metropolitan.bg - accessed on 08.03.2018)
According to the technical and economic report on the metro and the approved General City Plan, the General scheme should consist of three lines, with total length of 65 km, 63 metro stations, and 1.2 million daily passenger capacity at the final stage of implementation. The length of these three lines is 29km, 17km and 19km. The first line serves 23 stations, while the second and third will serve 17 and 23 stations respectively. All three lines intersect triangularly at the city centre (Figure 3).

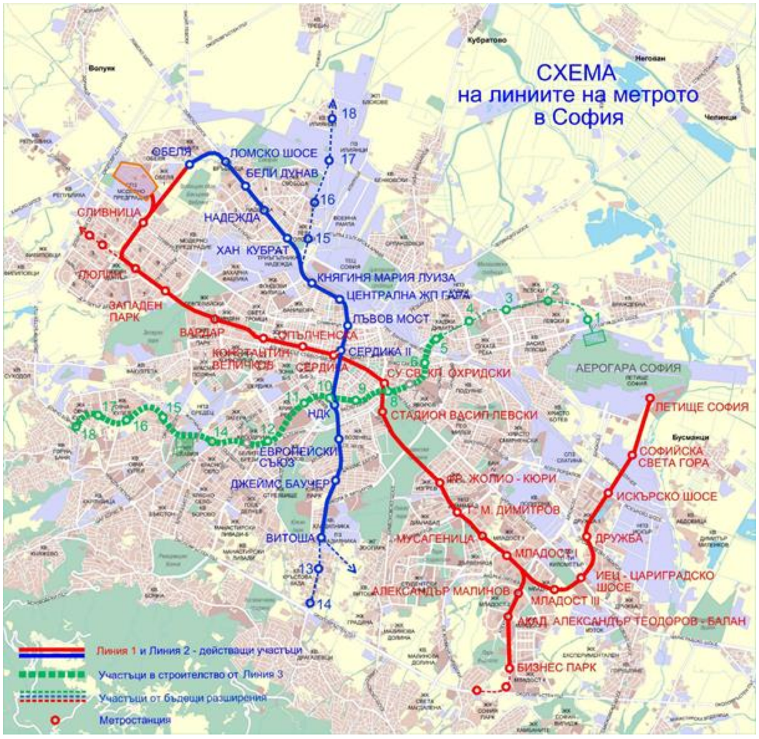


Figure 3. General scheme for the development of the metro lines according to the General Master Plan of Sofia (source: https://metropolitan.bg)

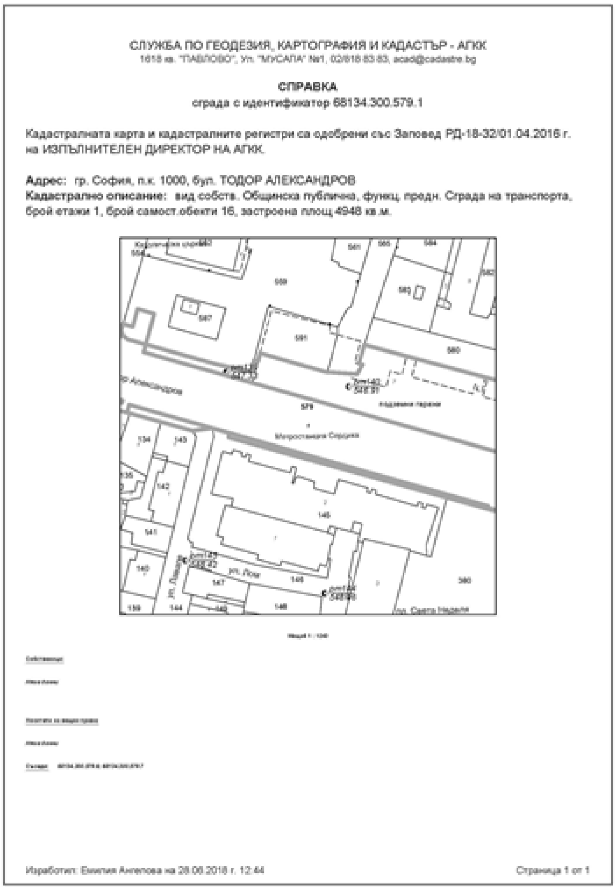
In future it is planned that Sofia Metro's Line 1 will be extended towards the south-east leading to the airport. The branch to the airport began in 2010 and is expected to be complete by 2020. Sofia Underground was voted Bulgaria's most-successful infrastructure project of the 2007-2017 decade. Sofia Mayor Yordanka Fandakova received the award for Sofia Municipality's contribution for the development of the city underground (http://bnr.bg/en/post/100949481/sofia-underground-is-bulgarias-most-successful-infrastructure-project-of-the-decade - accessed on 03.08.2018).

In Bulgaria the registration of the underground utilities is still in 2D. Usually the underground constructions as tunnels follow big public roads. However, there are parts which intersect with private properties. When the plans for metro creation started the owners which properties intersected with the territory for metro construction were contacted. Therefore, negotiations for compensation for their properties were done and contracts including each detail were signed. For each new line of the metro between 30 - 50 parcels needed to be negotiated between the Sofia municipality and the owners. It was observed that the initial price offered by the municipality was quite different compared to the price given from an expert appointed from the court. Therefore, a lot of appeals in the court followed until the agreement was achieved for both parties (https://www.dnes.bg/sofia/2011/08/21/stolichnata-obshtina-se-byrka-dylboko-za-otchujdavane-na-imoti.126915 accessed on 20.08.2018)

The Sofia underground is shown on the cadastral map even still in 2D. It can be freely accessed from the geoportal maintained by GCCA as shown on (Figure 4). Sometimes depending on the construction and architectural companies involved in its creation 3D plans and visualisations are attached in the system.

Figure 4. Central metro station Serdika extracted from the GCCA system requested by Emilia Angelova

The information visible in Figure 4 is publicly available according to Cadastre and Property Register Act (http://www.unece.org/fileadmin/DAM/hlm/prgm/cph/experts/bulgaria/documents/LCPR.pdf - accessed on 03.08.2018) which has been adopted in 2000. In blue color the outline of the property for the underground metro is underlined. What is visible is the current ownership which is municipality, the functionality which is construction for transport which includes 16 self-constrained objects (SCO) objects (apartments, studious, shops, garages, recreation and health centres etc.) covering area of 4948 m^2 and the address. The numbers of the neighbouring parcels are also accessible. If someone requests an official report for this particular metro station an automatic output can be generated as shown on Figure 5. However, all information about the former ownership is not visible for citizens. It can be provided only to the owner or notary.



СЛУЖБА ПО ГЕОДЕЗИЯ, КАРТОГРАФИЯ И КАДАСТЪР - АГКК
1618 кв. "ПАВЛОВО", Ул. "МУСАЛА" №1, 02/818 83 83, acad@cadastre.bg

СПРАВКА
сграда с идентификатор 68134.300.579.1

Кадастралната карта и кадастралните регистри са одобрени със Заповед РД-18-32/01.04.2016 г. на ИЗПЪЛНИТЕЛЕН ДИРЕКТОР НА АГКК.

Адрес: гр. София, п.к. 1000, бул. ТОДОР АЛЕКСАНДРОВ
Кадастрално описание: вид собств. Общинска публична, функц. предн. Сграда на транспорта, брой етажи 1, брой самост.обекти 16, застроена площ 4948 кв.м.

Изработил: Емилия Ангелова на 28.06.2018 г. 12:44 Страница 1 от 1

Figure 5. Report for the Metro station Serdika from GCCA requested by Emilia Angelova. Scale 1: 1243

3.3 Subway in Czech Republic

Prague is the only city in the Czech Republic with a subway network. The subway network is the core of the entire public transit system with 61 stations on three lines (A, B and C) with a total length over 65 km. Nowadays, the subway network is going to be extended for the new line D.

The new Civil Code (Act No. 89/2012 Coll.) considers the underground construction characterized by separate special-purpose use (like a subway) as a real property. However, in practice, many underground constructions are not registered in the cadastre. Currently, underground constructions are only registered in the case when some part(s) of the construction is located above the ground. After January 1, 2014 also Czech real estate law returned to the "superficies solo cedit" principle (Janečka and Souček, 2017).

The subway is often located below the parcels of other owners. There are on principle several ways of negotiations with landowners during a project planning: the landowner can sell his parcel or an easement can be established. The last option is so called temporary land take (a kind of lease contract). The established easements are then registered in the cadastre and visualized on 2D cadastral map. The right of easement is related to the (part of) 2D surface parcels. The (2D) spatial extent of the easement depends on the agreement between the parties (participants). The formalities of the proposal for entering the easement into the cadastre consists (among others) of document, based on which the right should be registered, indication of participants, indication of real properties to be registered. In case that the subject of registration has to be depicted in the cadastral map, then the survey sketch is an inseparable part of the document.

The underground parts (tunnels, stations) of the subway network are neither registered in the cadastre nor drawn on the cadastral map. Only the parts of the subway network (partially) located above the ground are registered in the cadastre and displayed on the cadastral map in the same way as are the buildings or bridges as depicted in Figure 6.

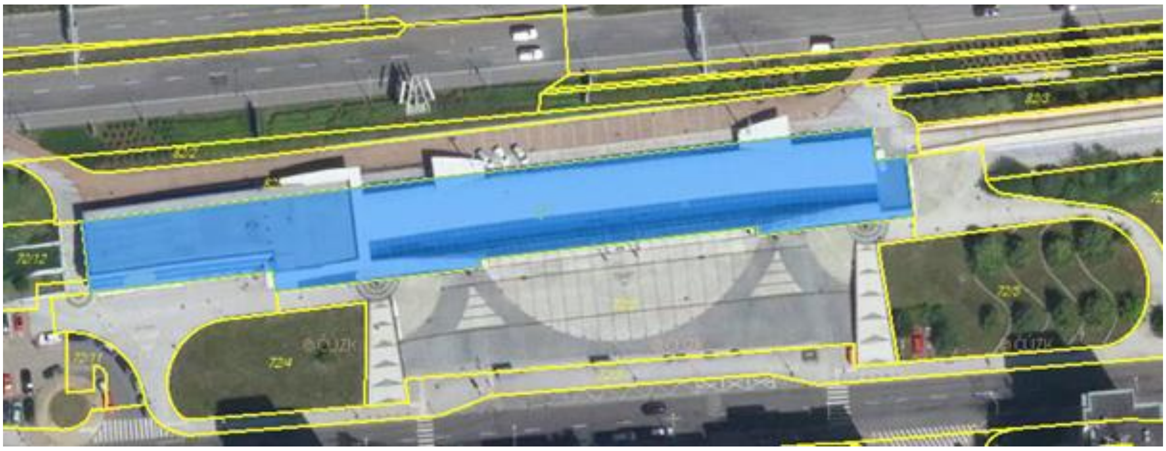


Figure 6. The parcel with metro station located above the ground (highlighted in blue colour). In the cadastre, there is information that a building (without building/registration number) stands on this parcel

It also happens that part of the subway is located in some height above the ground e.g. in tunnel. In such case the outdoor tunnel is not drawn on the map (Figure 7).

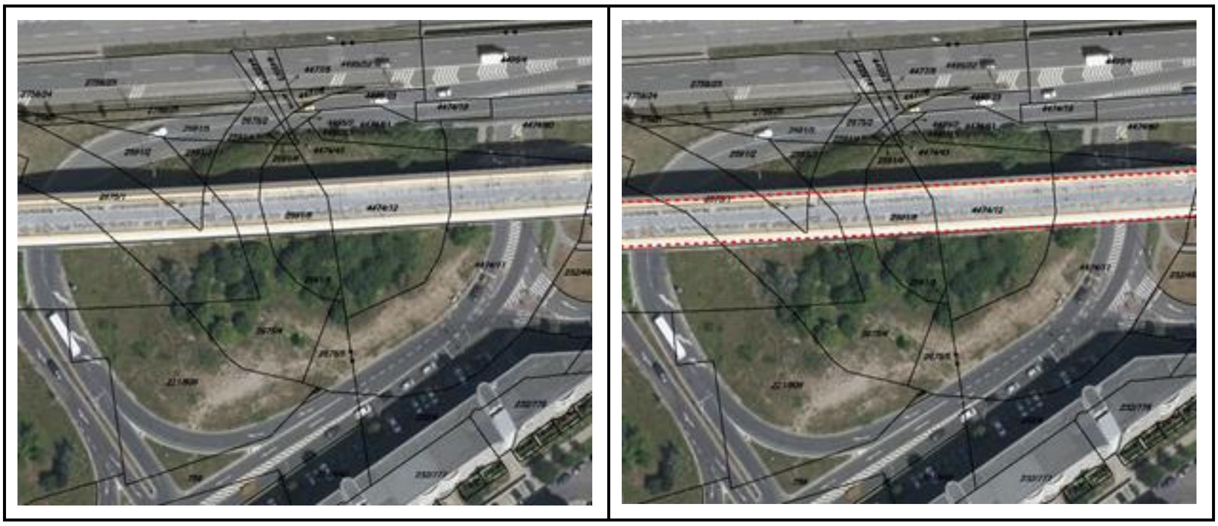


Figure 7. Even if a part of the line B is located inside the outdoor tunnel, it is not reflected on the cadastral map (left). Here in the figure the outdoor tunnel is highlighted with red dashed line (right)

3.4 Subway in Greece

Greece is currently under cadastral survey in order to complete the Hellenic Cadastre project. Hellenic Cadastre is regulated by Law 2664/1998, while cadastral survey procedure is regulated by Law 2308/1995 and its later amendments. According to Law 2664/1998 (art. 12), Hellenic Cadastre records all deeds that establish, transfer, change or abolish rights on real property. Inheritance, seizures, long-term leases, administrative acts and court decisions are among the registrable rights on the Hellenic Cadastre. Registrable rights' declaration is required by every natural and legal person that has such rights on real property.

In Greece, subway system is established to serve mass transit to the conurbation of Athens, while subway system is under construction in the city of Thessaloniki in Northern Greece. Subway system of Athens (Attiko Metro), comprises of two lines, while it has also incorporated the former railway line joining Athens with the port city of Piraeus. Currently, Athens subway network covers length of 85.4 kilometres with 61 operational stations, while its main part is underground. Further extension of the subway system is already on-going, while a fourth line has been designed and construction works are anticipated to begin in 2019 (Attiko Metro, 2018). Figure 8 presents operating and planned development of Athens subway in the region of Attika.

Figure 8. Athens metro lines development plan (Attiko Metro, 2018)

Cadastral system in Greece does not provide for registration of subway lines. Surface parcel ownership does not imply ownership of the subway line, but this cannot be identified in the cadastral registry. Greek Civil Code is in accordance with the Roman principles on real property (art. 948, 952, 1001). However, the same articles limit the vertical extent of surface parcel owners' rights to the height and depth "that the owner has no practical interest in opposing against it". The greatest part of Athens' subway system is developed below public roads, while a smaller part is developed below private property. Provisions of the establishing law of Attiko Metro (Law 1955/1991, art. 10, par. 1) stipulate that all works related to the development of the subway network are considered as public interest works and all real property units required for the subway project's development are expropriated under the Expropriation Law. Surface parcel owners are obliged to tolerate the construction of tunnels and all other works related to the development of the subway network without any compensation, as long as current use of the land surface parcel is not affected (Law 1955/1991, art. 10, par. 2). Similar regulations can be traced in the law on the establishment of Thessaloniki subway line (Law 2714/1999). Consequently, only those real property units that have been expropriated can be identified in the cadastral records. Even in such case, registration refers to the surface parcels, not subsurface space.

3.5 Subway in Sweden

When legislation allowing the formation of 3D property was introduced in Sweden in 2004 (SFS, 1970:994), it was partly as a response to needs from the building industry and for fulfilling certain demands. A demand that had existed quite some time was the possibility of dividing ownership of buildings or space below ground, so that there could be separately owned property units for these purposes (Julstad and Ericsson, 2001, p. 174). Apart from requesting the possibility of adding an additional separately owned storey on top of existing buildings in cities for housing purposes, the implementation of major infrastructure projects was another specified need (Eriksson, 2005, p. 12).

Even though there is no fixed delimitation of the volume of the traditional real property unit above or below the ground surface, it is still possible for the property owner to construct infrastructure facilities above or below ground within the volume of his/her property. This can even be done by another party with the consent of the owner or without consent through expropriation means, normally providing compensation for the take. Before the possibility of forming 3D property units with ownership was introduced into Swedish legislation, other less secure and lasting forms were used for the establishment of infrastructure rights, such as establishing joint facilities, granting easements, utility easements and different kinds of leaseholds. The disadvantages connected with these solutions include e.g. that rights of use constitute personal property and cannot be separately registered or mortgaged in Sweden as real property can be (Julstad and Ericsson, 2001, pp. 174-179). When the subway in Stockholm was constructed during the 20th century, 3D property formation did not exist and because of that a rather unusual legal solution to secure rights had to be used that was not very suitable for the purpose. An easement was created for the entire subway tunnel system, connected to one small property unit belonging to the subway system (Julstad, 1994, p. 120).

With the existing lack of space in urban areas, there is an increasing need for more intensive use of land and space to use space below and above ground for different purposes and by different users. In the governmental investigation preceding the 3D property formation legislation (Proposition 2002/03:116, pp. 31-32) one of the needs for the use of 3D property mentioned was in fact related to large complex projects with a need for extensive funding. It was then considered to be a better solution to subdivide these properties and facilities into separate property units, both when it comes to management and for financial reasons. One example mentioned where 3D property formation was considered to be a valuable tool for solving complicated problems within building projects and for various purposes was covering railway areas with buildings for housing and offices and using space below ground for garages and archives, as well as for dividing ownership within different communication areas with terminals, bridges, railway stations, etc. By using this instrument, it would be possible to construct residential buildings on top of railway tracks or public space. The created right would then be independent in relation to the traditional property unit within which the space is located and thus be possible to transfer independently without the surface area and to mortgage as any real property. It should also be possible for authorities, mortgagers and others to receive knowledge about the property right through the property registers.

The instrument 3D property space, with the purpose of delimiting space that is more suitable to add to another property unit than where it is located, could also be used for infrastructure purposes, for example a parking space protruding below a building within another property. 3D property formation for communication purposes is also suited for more rural areas and not just densely built-up urban areas. Examples of such infrastructure are road and railway tunnels and bridges. One urban example is the Stockholm City lane. It is a large project which contains a new railway tunnel below Stockholm city where four connected 3D property units for railway purposes are formed for the railway tunnels (Jarnestedt, 2009, pp. 2-3). Other facilities underground where 3D property may be of use are rock cavities that are no longer of any use for the owner of the land parcel. An illustration of 3D property formation for underground tunnels for infrastructure purposes can be found in Figure 9. The space containing the tunnel forms a separate 3D property unit, surrounded by the ground space of the traditional property unit that also includes the land surface. This is what it looks like e.g. in the case of the Stockholm City lane.

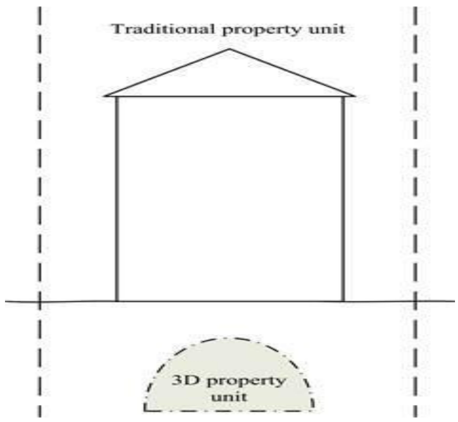


Figure 9. Example of 3D property formation for underground tunnels in Sweden (Paulsson, 2013, p. 201)

There are no specific rules provided in the legislation regarding where the boundaries surrounding the underground tunnels, and thus delimiting the 3D property unit, should be drawn. It is decided in the specific case. The recommendations (Lantmäteriet, 2003, p. 68), however, give the possibility to include a protective area around the tunnels in the 3D property unit, for protection from damage by surrounding properties or for management purposes. An easement can also be created for this purpose, thus being a protective area included in the surrounding property unit.

The 3D property units are registered in the cadastral index map (Lantmäteriet, 2004), which is part of the national Real Property Register, and in the textual part of the register. They are in the textual part recorded with the purpose “4=Tunnel” (Lantmäteriet, 2016), see Figure 10. The registration does however not differentiate between different types of tunnels. Today, in total 46 3D property units are registered with the purpose “tunnel” in the national real property register.

6.	UTRYMMESTYP	2	N	UTRYMMESÄNDAMÅL 1 = Bergrum 2 = Bro 3 = Byggnad 4 = Tunnel 5 = Övrig Anläggning REDOVISNING AV ÄGARLÄGENHETFASTIGHET 6= Ägarlägenhetfastighet	J

Figure 10. Purposes of 3D property registered in the Swedish national real property register (Lantmäteriet, 2016, part of table 09D)

The majority of these 3D property tunnels are not used for subways, but some in the Stockholm region are, as mentioned above. 3D property formation is now being used when new subway tunnels and stations are constructed, see Figure 11, showing a new subway station on the Stockholm City lane.

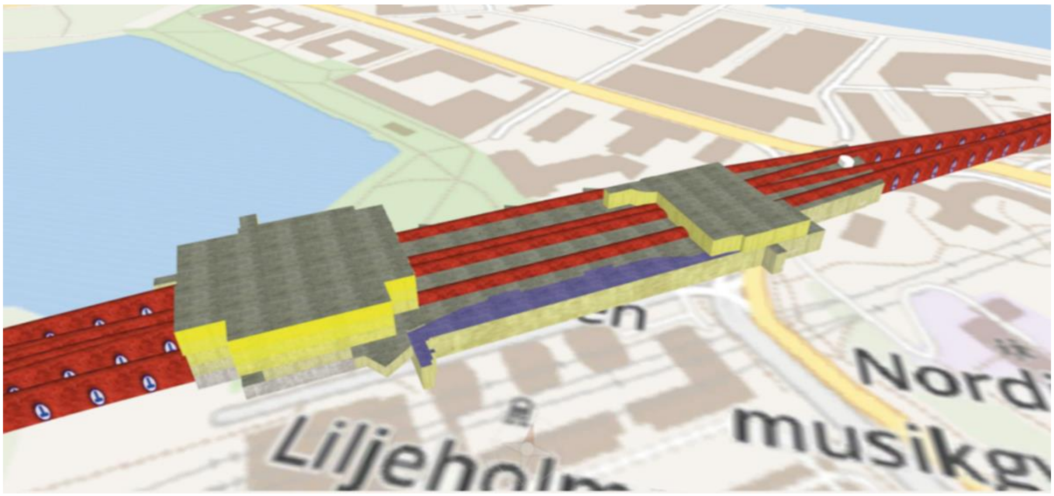


Figure 11. 3D property formation of subway station in Stockholm (Source: http://www.sl4d.se/pilotprojekt-3.html)

The introduction of 3D property formation into the Swedish legislation has thus increased the possibilities of more secure and clear ways of constructing, financing and managing in particular large and more complex facilities, such as infrastructure objects, by separating it legally from other types of use within the space of the same ground property.

3.6 Underground tunnels in Slovenia

In Slovenia, there are no cities with a subway network. This does not mean, that there are no challenges in registering the underground traffic objects, such as road or railway tunnels, that are crossing the complex urban environment and are often intersecting private property. Like in the other countries included in the study, the Slovenian land administration system is based on the principle "superficies solo cedit", that is, the ownership of a piece of land generally comprises also the ownership of all constructions erected on the land. Exceptions to this principle are (1) the right of superficies (the right to own a building above or beneath the land owned by a third person), and apartment ownership (condominium).

The roots of the Slovenian land administration system are in the Austrian cadastre, and is still based on 2D-graphical representation of the land parcels. This traditional 2D-cadastral approach did not allow the registration of the real properties if a traditional land parcel needed to be vertically divided. For the purpose of registering parts of buildings (condominium), an additional, but with the land cadastre linked database - the building cadastre was established based on legislation from 2000 (Drobež et al., 2017). The right of superficies and apartment rights separate the ownership of physical objects from the land itself.

According to Slovenian legislation, a building is a construction a person may enter and is designed for their permanent or temporary residence, conducting a business or any other activity and cannot be moved without damage for its substance. The problem arises where the horizontal interest overlapping appear related to other construction objects, that are not classified as "buildings". For the registration of tunnels, as the study case, there is no particular solution in the current land administration system. Registration of rights in this case might be different from case to case as it is dependent on the time of the registration as well as from the negotiations between the land plot owners and investors. Purchasing of land plots in the cases of tunnels (as well as bridges, viaducts) are not a common solution and is not appropriate for the dense urban environment. The most common solution is registration of easements in the land registry, where land plots over a tunnel (under the bridge/viaduct) are encumbered. Unfortunately, there is no graphical presentation of infrastructure objects ("occupied space") neither in the land cadastre nor in the building cadastre. As shown on Figure 12, infrastructure objects are registered in the land cadastre as land plots when the objects is in the land "surface", in the case of tunnel, the railway company is not the owner of the land plot.

Figure 12. Left: railway (red) with the tunnel (green) and road (blue); right: the land plot and ownership structure (Source: PISO, https://www.geoprostor.net/piso)

Easement boundaries are not included in the cadastral maps and thus the extent of the easements is only evident from the documents in the land register.

3.7 Underground tunnels in Croatia

In the Republic of Croatia there are no cities with a subway network. Underground traffic objects, such as road or railway tunnels are registered in Croatian Land administration only on topographic maps.

An example of tunnel representation in the Croatian Land Administration System is shown in Figure 13. The tunnel, which was built under many cadastral parcels, would, in a vertical sense, belong to those cadastral parcels. However, by functionality, it is permanently connected to the land where the entrance to the tunnel is located, and not to the cadastral parcels that extend above it (Vučić et al. 2017). Therefore, according to legislation, the tunnel is permanently connected only to the land where the entrance is which makes it one property. Further development of software and hardware technologies for spatial information has made it easy to combine geodetic and cartographic products in the modern digital environment. Today, all Croatian cadastral offices maintain digital cadastral maps overlapped with orthophoto images, and all other geodetic and cartographic products are available on the Croatian SGA Geoportal available on web address: https://geoportal.dgu.hr.

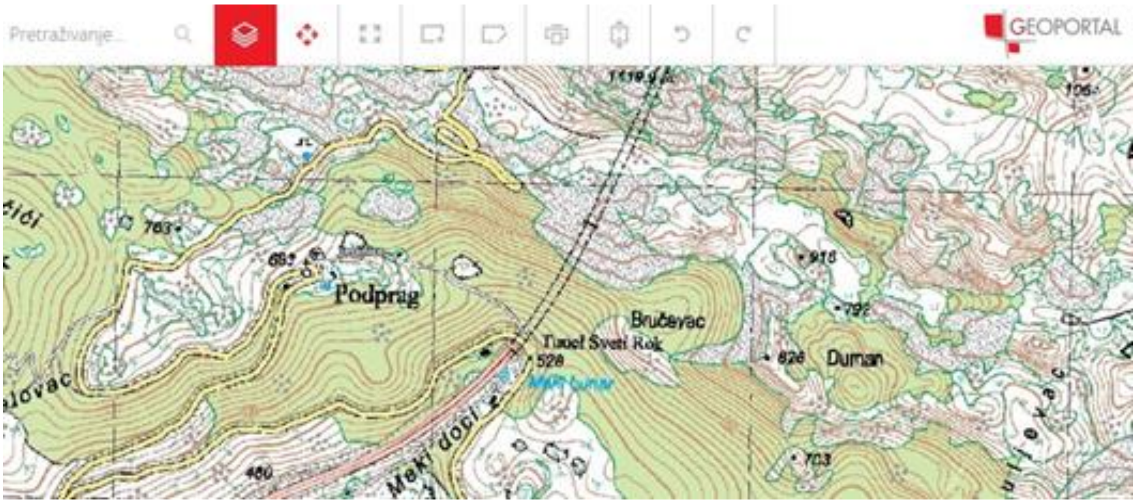


Figure 13. Tunnel as seen on a 1:25000 topographic map

At this point tunnels are not recorded in the land register, although the number of inquiries for enrollment of such or similar situations is rising. While in cadastre, tunnles are recorded only on the cadastral plan (with topographic symbol). In last several years there have been significant rise of official inquiries for enrollment of 3D cadastral situations into official registers. In particular for underpasses and overpasses, where they overlap with natural objects or private, often built, property.

3.8 Subway in Poland

Warsaw is the only city in Poland with a subway network (Figure 14). The subway network consists of 2 lines (M1 and M2). M1 line consist of 21 stations and have length about 23km, M2 line is now under construction (7 stations from 21 are finished and fully operational, total planned length is 31km).

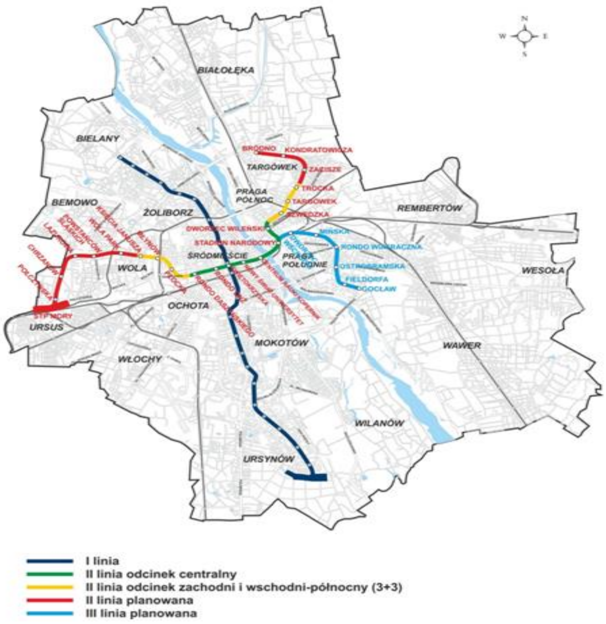


Figure 14. Metro lines in Warsaw. Navy Blue – M1 line (fully operational), green M2 line (fully operational), yellow M2 line (under construction), red M2 line (planned), blue M3 line (planned) Source: http://www.metro.waw.pl/ii-linia-metra-109

The entire route of the underground railway is traced under the lands being the property of the Capital city of Warsaw. For line M1 the route is located under the main streets of the city and the tunnel route exceeds the streets in the case of big stations only. For line M2 the route is crossing parcels with buildings but those buildings are located on land owned by the city. Therefore there was not necessary to establish limited rights related to tunnels. They are not cadastral objects as well (Karabin, 2011).

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.

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.

For tunnels the full technical documentation is stored at Metro Warszawskie company. Those documents are post inventory documentation made using tachymetrics surveys for stations and tunnels realized via strip methods and made using laser scanning. Finally the public accessible information about tunnels is included on the base map only and has the form of projections of tunnels' edges (Figure 15).

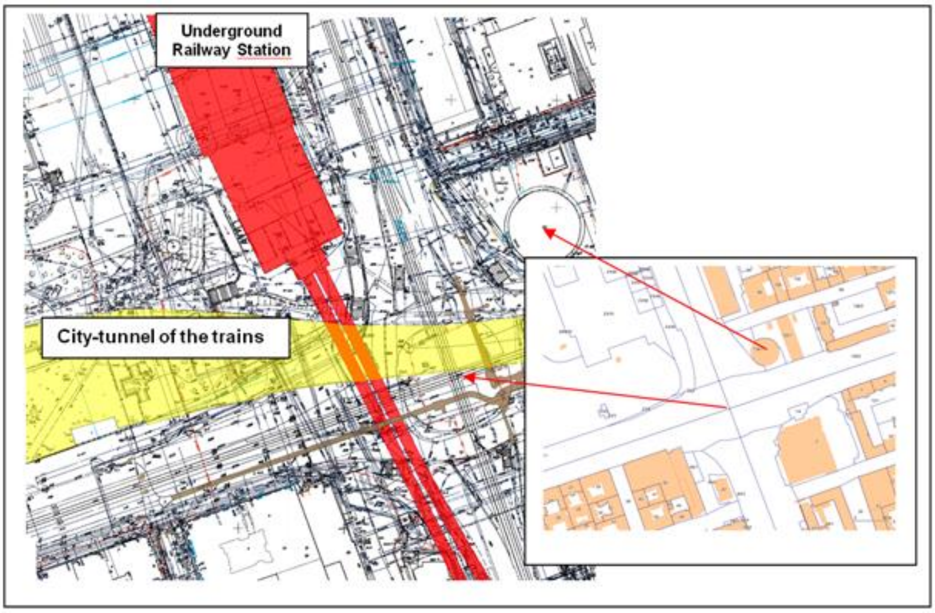


Figure 15. Subway data on a cadastral and base map Source: The Office of Geodesy and Cadastre for the City of Warsaw – published in Karabin (2011)

The basic surveying data, which exist at the Metro Warszawskie Company, are the data of the post-implementation inventory of the tunnels. Terrestrial laser scanning (TLS) method was used for inventory surveys for M2 line. The measurements were performed using Imager 5006i of Zoller+Fröhlich GmbH with the reference to points of the geodetic control (PUH "GeoCad" Sp. z o.o. (2014)).

This documentation has a status of "for internal use only" because of security of object and "top secret" status of subway. It is generally forbidden to publish any detailed information concerned precise location of subway in a national reference frame and open this information to the public.

In Warsaw University of Technology conducted experimental works concerning integration of data from terrestrial laser scanning of inside of two subway tunnels with cadastral data (cadastral map) and ALS data and DTM data of terrain above tunnels. As a result it was created integrated 3D models of underground and terrain (Figure 16). The ArcGIS 10.5 and ArcGIS Pro software applications were used for the generation of the 3D tunnel models and for the spatial analyses. In detail it was described in (Karabin et al., 2018).

Figure 16. 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, published in (Karabin et al. 2017)

Experimental works proved that it is possible to get sufficient accuracy for the visualization of metro tunnels and use it in cadastral studies and works. Finally it is possible based on created 3D model to divide the space of cadastral parcels into layers and delineate 3D properties, which include subway tunnels. Used GIS software also allows to perform complete 3D analyses, which can be useful for designing other underground objects, crisis management etc. (See also Karabin et al., 2018)
Based on experimental studies you may say that there are technical possibilities of 3D cadastre implementation in a case of subway. On the other hand it is not possible from legal point of view. There were some initiatives concerned introduction of independent ownership of the built objects such as underground tunnels, viaducts etc. but those ideas not passed legislation process. Superficies solo cedit rule is still operating in a case of subway.

4. SUBWAY'S REGISTRATION IN 3D CADASTRE – THE BENEFITS

Obviously, there may be difficulties involved with combining different activities within the same surface property unit which are not suited to manage by the same owner. If the possibility of 3D property formation is not present within a legal system, other less secure and lasting forms will have to be used. Such forms can be different types of indirect ownership or granted user rights, such as joint facilities, easements, utility easements and leaseholds (Paulsson, 2013). These solutions are however not always optimal and involve certain disadvantages or not be suitable for its purpose. One of them is the missing visibility of rights including public law restrictions, which has a dramatic effect on land value (Twaroch and Navratil, 2016). In this case, a division into 3D property units will be a good tool to separate these activities with independent ownership for these activities, where each part can be mortgaged and used as collateral.

The transaction costs occurring when purchasing, exchanging, transferring or in other ways changing the rights are also higher when using different kinds of rights, or may need the consent of the property owner before transferring them (Ekbäck, 2011). Benefits that can come legally securing the three-dimensionally delimited parts of the property are securing the value of real property for the users of it by removing obstacles such as the limitation of rights that can lapse and increasing the possibilities for the right holder to make changes to the property according to needs.

A benefit of a 3D cadastre is thus the improved documentation of rights. In the context of subways that guarantees durability and accessibility through standardized interfaces and therefore improves information for future underground development. It opens the path for 3D spatial planning. Currently zoning plans are only done in 2D. This can cause problems when trying to develop underground space because constructions may be realized between the planning and the implementation of some infrastructure project, which prevent the realization of the project.

5. CONCLUSIONS

Registration of underground infrastructures constitutes a challenge for national land administrations systems, due to national legal specifications and the unique characteristics of underground objects. The limited number of underground subway projects in all the examined countries (mostly subway network is developed in one city of each country) does not provide sufficient experience on registration of stratified, underground space. “Superficies solo cedit” operates restrictively on real property stratification. However, Czech Civil Code circumvents aforementioned principle by regarding underground special-purpose constructions as separate real property. In the majority of the examined countries subway network is developed, partially or entirely, below municipal or state owned land. In case of land parcels owned by private individuals, two options are identified. In the first one, the whole land parcel gets expropriated for public benefit purposes, e.g. Greece, while the second option involves the establishment of servitudes, e.g. Austria and Czech Republic. Cadastral registration of underground infrastructures is not required in most of the examined countries, except of Bulgaria, therefore, subway network is not presented on cadastral maps. Exceptions may refer to the presentation of subway stations lying on the surface parcels. However, registration of servitudes remains limited to 2D space, potentially including cross-section diagrams as well. It needs to be noted that despite the lack of cadastral documentation of subway networks, detailed diagrams of subway networks are maintained by the agencies responsible for each network’s operation.

A different approach can be traced within the Swedish framework, deriving from the statutory establishment of 3D real property units in Sweden. In such case, 3D real property units are established for the vertical partition of the 3D space required for the development of subway tunnels, also registered to the Swedish cadastral index map.

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