3D Cadastre in the Case of Engineering Objects, such as Bridges and Road Viaducts

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

Key words: 3D cadastre, road viaduct, bridge, layer approach

SUMMARY

At present, the implementation of cadastral registration of transport investments (such as railway lines on bridges and on viaducts, roads on viaducts, etc.) is performed in the so-called "layer" system. This means that many objects are constructed at different levels (layers) within the space of a given parcel. Several parties may be interested in developing certain fragments of the parcel space; each of them is interested in acquiring rights only to a specified part of the parcel (its specified layer), in which given investment is implemented by that party. The legal conditions binding in many countries do not allow for implementation of such type investments within the space of a someone else's cadastral parcels, based on the ownership right. This is due to the fact, in accordance with the "superficies solo cedit" rule applicable in many EU countries, the ownership right extends above and below the parcel space and cadastral systems do not allow for vertical division of a real property. The conventional 2D cadastre, which does not allow vertical division of the parcel space, forces an investor to buy a whole parcel or to get other rights which allows using a specified space of someone else's parcel, such as easiment rights. Buying of an entire parcel in which space bridges and road viaducts investments will be performed and not being able to divide the land space vertically makes it practically impossible to sell the parcel under a viaduct because following the rule above the viaduct is part of the land parcel. Therefore, the space is not optimally utilised. The easement right has some disadvantages, as it cannot be encumbered with a mortgage; therefore it is not the basis of crediting a given investment. The 3D cadastre allows delineating 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 the implementation of a line investment in the above-ground 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 bridge or viaduct. This paper focuses on approaches to registration of real property rights in the case of engineering objects, such as bridges and road viaducts, in different EU countries: Austria, Bulgaria, Czech Republic, Croatia, Greece, Poland, Slovenia and Sweden.The authors review the current solutions for the registration of engineering objects in the cadastre, including its effectiveness in ensuring appropriate property rights to construct and exploit such objects, and make a comparison between the countries.

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1. INTRODUCTION

At present, the implementation of cadastral registration of transport investments (such as railway lines on bridges and on viaducts, roads on viaducts, etc.) is performed in the so-called "layer" system. This means that many objects are constructed at different levels (layers) within the space of a given parcel. Several parties may be interested in developing certain fragments of the parcel space; each of them is interested in acquiring rights only to a specified part of the parcel (its specified layer), in which given investment is implemented by that party. The legal conditions binding in many countries do not allow for implementation of such type investments within the space of a someone else's cadastral parcels, based on the ownership right. This is due to the fact, in accordance with the "superficies solo cedit" rule applicable in many EU countries, the ownership right extends above and below the parcel space and cadastral systems do not allow for vertical division of a real property. The conventional 2D cadastre, which does not allow vertical division of the parcel space, forces an investor to buy a whole parcel or to get other rights which allows using a specified space of someone else's parcel, such as easiment rights. Buying of an entire parcel in which space bridges and road viaducts investments will be performed and not being able to divide the land space vertically makes it practically impossible to sell the parcel under a viaduct because following the rule above the viaduct is part of the land parcel. Therefore, the space is not optimally utilised. The easement right has some disadvantages, as it cannot be encumbered with a mortgage; therefore it is not the basis of crediting a given investment. The 3D cadastre allows delineating 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 the implementation of a line investment in the above-ground 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 bridge or viaduct.

This paper focuses on approaches to registration of real property rights in the case of engineering objects, such as bridges and road viaducts, in different EU countries: Austria, Bulgaria, Czech Republic, Croatia, Greece, Poland, Slovenia and Sweden. The authors review the current solutions for the registration of engineering objects in the cadastre, including its effectiveness in ensuring appropriate property rights to construct and exploit such objects, and make a comparison between the countries.

2. REGISTRATION OF BRIDGES IN EU COUNTRIES (NATIONAL SOLUTIONS)

2.1.Austria

The Austrian system does not support the registration of 3D property. A viaduct can be modelled like a building. The areas required for the viaduct are separate parcels. Street crossings are separate parcels where road and bridge intersect.

The situation for bridges is slightly more complicated. Bridges may be close to the surface like in the Stadtbahn example. However, they may also be high in the air. An extreme case is the Europabrücke in Tyrol (see Fig. 1 left), which has a maximum height above ground of 190m and a length of 777m. The pure cadastral boundaries only show the footprints of the pillars (Fig. x4 right). The bridge is marked in the cadaster only as a land use type. Fig. 2 shows a detail of the area with parcel 593 in the center. The parcel has a total size of 24,319m2 and 4,077m2 of them are used for traffic infrastructure. However, the owner of the total parcel is not the operator of the highway. The legal basis of the construction is an easement based on an administrative decision and inscribed in the land register. The text is "*Easement of the superstructure, the maintenance and the operation of the Europabrücke on Gst 593 598/15 601/10 in accordance with decision 1984-12-13 for Republic of Austria (Bundesstraßenverwaltung - A)*". Accessing the original legal document is difficult since it either requires a visit at the locally responsible land register or a search for the decision itself. It is thus not obvious who the owner of the construction is. It could be the Republic of Austria, it could also be ASFINAG, the Motorway and Expressway Financing Corporation, a company owned by the Republic of Austria, which was founded in 1982 and operates the highways in Austria.

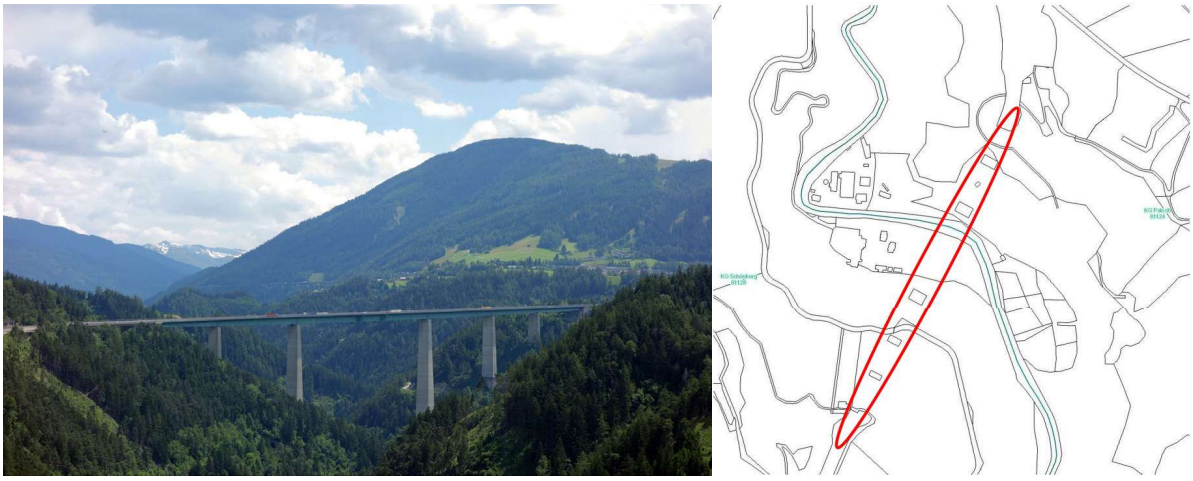

Figure 1. left: Europabrücke in Tyrol, Austra (Source: Von Mnolf - Eigenes Werk, CC BY-SA 3.0, https://commons.wikimedia.org/w/index.php?curid=27116002, 2013); right: cadastral boundaries in the area of the Europabrücke, red ellipse marks the area of the bridge (Source: BEV)

Figure 2. Cadastral map including the land use types (Source: BEV)

2.2.Bulgaria

The first cadastral law with an objective to determine the legal and physical property boundaries aiming for correct geolocation and fair taxation was passed in 1908. Bulgarian Civil Law incorporating the deed registration system was built following the Roman legal system. In 1990 nearly 90% of the territory of the country was restituted. This action was followed by the creation of a new Law on Cadastre and Property Register (LCPR) in 2000, clarifying the rules related to the data collection, exchange, and maintenance between the property register of the Ministry of Finance, register of people and companies. The Agency of Geodesy, Cartography and Cadastre is the one responsible for cadastral data production and maintenance.

The produced cadastral maps include data related to the ownership, property rights over the immovable properties, state and land property boundaries. Moreover, it is shown if the land is urban, agricultural, forestry or other. The Cadastre and the Property Register, which keeps data on property transfers, maintain a constant link. All property transactions in Bulgaria are done with the help of private notaries and licensed surveyors and are registered in the Registry Agency. The Bulgarian cadastral system manages data in 2D format, however for certain complicated situations, additional 3D materials are attached. In Bulgaria, some bridges are visualised in the cadastral map without a unique identifier as shown on Fig 3 since they are not considered cadastral objects.

Figure 3. "*Luvov most*" and "*Orlov most*" in Sofia. (www.isofmap.bg)

They are either state or municipality property and fall under the laws related to the transport, technical infrastructure and their facilities. This means that activities related to their construction and maintenance are responsibilities of the state or the municipality. Special approval for their building, including technical specifications and specialised schemes, is needed. Data for creating such specialised maps are retrieved from the central administration system. Usually, it is obtained from the cadastral agency in digital form and contains information about the spatial location (state borders), boundaries, the way of use, ownership, rights, restrictions and responsibilities. In the law, it is written that the underground and common surface networks and facilities of the technical infrastructure should be designed and constructed on municipal and state landed properties. In case this is not possible, they should be constructed in properties owned by individuals or corporate bodies (art. 199 or 205).

After applying for many years the Cadastral Law created in 2000 due to observed challenges in registration of certain complicated urban situations, changes in the law have been done in 2014. One of the changes was related to the registration of infrastructural objects (e.g. bridges) in the cadastral map. A typical complicated example is when there are commercial structures positioned on top or under infrastructural objects such as bridges. With the acceptance of this law, it is currently possible to register such objects independent from the utilities and infrastructure.

2.3. Czech Republic

There are some kinds of 3D objects schematically displayed on the 2D digital cadastral map, but in fact not officially registered in the cadastre, which is also the case of bridges. Fig. 4 displays a combination of the digital cadastral map (and the outlines of the bridge in the center) and the orthophoto map. The bridge is owned by a private person, but the cadastre does not contain any information about the ownership. According to the Civil Code, the ownership is proved just by the purchase contract.

Figure 4: The private bridge schematically displayed in the digital cadastral map. (Czech Office for Surveying, Mapping and Cadastre).

Sometimes the digital cadastral map contains only these parts of the bridge, which are directly connected with the ground (Fig. 5) and sometimes the bridge is completely missing.

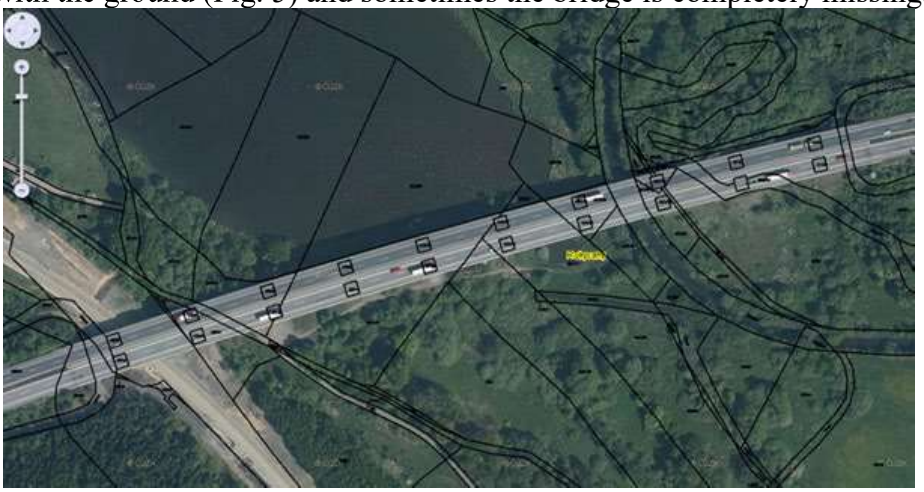

Figure 5: The bridge near Pilsen which is a part of the highway from Prague to Pilsen. Only the parts of the bridge connected with the ground are graphically displayed.
(Czech Office for Surveying, Mapping and Cadastre).

2.4.Croatia

In the Croatian Land Administration System, there are special topographic signs for 2D maps showing 3D situations such as buildings overlapping other structures (e.g. tunnels, roads, or other parcels with building parts crossing the parcel boundaries either above or below ground level). Additionally, there are also special signs that represent underground buildings on cadastral and topographic maps (Fig. 6). Cadastre can register underground buildings only on cadastral maps and in the written part of cadastral documentation, but without area information, which can be documented in the land register. Many new underground buildings were built in Croatia during the last twenty years, which is the reason behind the consideration of new regulations by the State Geodetic Administration of the Republic of Croatia that will enable the registration of underground buildings with area and other attributes into the cadastre.

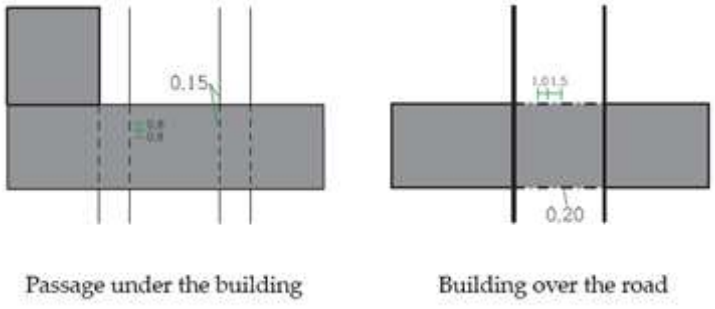

Figure 6. Example of topographic signs for buildings.

City of Neum (Bosnia and Herzegovina) divides Croatian territory into two parts. In July 2021 after a long time, Croatian territory was united by making a new bridge (Figure 7). The Pelješac Bridge is a bridge in the Dubrovnik-Neretva County in Croatia that bridges the Mali

Ston Bay between Komarna on the mainland and Brijesta on the Pelješac peninsula and thus achieves the continuity of the territory of the Republic of Croatia interrupted by a narrow corridor that leads Bosnia and Herzegovina to Neum.

Figure 7: Pelješac bridge (Https://www.obserwatorfinansowy.pl/wp-content/uploads/2020/01/Croatia-Peljesac-bridge-map-kwadrat-1-290x290.jpg (left); https://static.euronews.com/articles/stories/05/93/97/68/808x532_cmsv2_9ebb3473-bee3-55dc-865d-16d92f1d232b-5939768.jpg (right)_

The bridge is a suspension type, with a total length of 2404 m with six main pillars and thirteen spans of steel with a length of 72 to 285 meters. At a height of 55 meters, the request of Bosnia and Herzegovina to ensure the unimpeded passage of ships to Neum was met. The depth of the sea under the bridge is almost constant 27 meters, and due to the soil composed of thick layers of clay and silt, the entire bridge is based on a hundred meters long steel pipes with a diameter of two meters driven into the seabed. The location of the bridge is subject to strong winds and is in a zone of significant seismic activity. The bridge is located in a sensitive ecological area of the Mali Ston Bay, which was declared a nature reserve in the sea in 1983, and is also protected by the ecological network Natura 2000. Pelješac bridge is not registered in the Land cadastre and Land registry due to the missing laws regulating that matter, but State Geodetic Administration working on bylaw for all tunnels, roads, or other parts of parcels with building parts crossing the parcel boundaries either above or below ground level to be registered in Land administration system.

2.5 Greece

Greece belongs to the legal family of Civil Law. Real property is regulated by the Greek Civil Code (Book 3, Property Law). Land ownership comprises everything that is attached to land (art. 948), and extends to the space above and below the land surface. However, the land owner may not forbid an action taking place high or low enough to be of interest to him/her (art. 1001). Stratification of real property can be achieved through the establishment of servitudes, horizontal ownership rights (apartment rights/condominium), vertical ownership rights (the land owner has the right to create and register titles of independent properties that will be erected on the parcel in the future) and the right of superficies. Stratified real property objects pre-existing the introduction of the Greek Civil Code in 1946, known as special real property objects (SRPO), also constitute cases of 3D real property.

For the establishment of utilities, the Greek Civil Code provides that the land owner of a land parcel is obliged to allow utility networks to cross on, above, or below his/her land parcel after compensation (art. 1031). As regarding to major infrastructures, apart from the provisions of Property Law, special provisions can be made by legal statute (e.g. Law 2882/2001 (Expropriation Code) or Law 2714/1999 for the establishment of the subway line of the city of Thessaloniki in Greece that regulates issues of real property rights on and below the land surface). Bridges and viaducts are considered as public spaces, owned either by the State, or by the municipalities. Such types of objects are registered to the Hellenic Cadastre database and are assigned a unique cadastral number (KAEK). In order to avoid ambiguities and identify overlapping real property objects, the Hellenic Cadastre uses separate thematic layers for the spatial representation of mines (Rokos, 2001; Arvanitis, 2014). However, this solution was not extended in case of bridges and viaducts, due to their direct relation with their surrounding real property objects. Consequently, the real property object that is lying on top of the other is presented on the cadastral map, while the objects lying at a lower level are split based on the projection of the above lying real property object (Fig. 8).

Figure 8: Viaduct in the region of Attiki in Greece, as shown in the Hellenic Cadastre map (left) and real property units of the viaduct and its surrounding roads (right)
(Hellenic Cadastre web services for professionals)

This introduces ambiguities in representing the real situation on the cadastral map. Reference pointers (tags) relating cases of overlapping real property rights that are used especially for SPROs are also implemented in case of real property objects situated below bridges or roads (Sioula, 2011). Overlaps due to the existence of bridges and viaducts can be distinguished in two categories. The first comprises those that the real property objects below the bridge/viaduct are owned by the state (most commonly the Ministry of Infrastructure), or the municipalities and the regional authorities. In this case, there is no specific provision for the

distinction of the overlapping parts as regarding registration or presentation to the cadastral map, since it is considered that both of the overlapping volumes serve the public benefit. The second type of overlaps refers to bridges/viaducts situated above privately owned land. This case is more complex since the existence of the bridge/viaduct significantly affects the below-lying land parcel's exploitation and use. This issue has again been brought to debate, within the context of the ongoing cadastral survey of the rural part of Greece, where about 6,000 bridges of more than 6 metres length can be traced to the Greek national road network, in a total of about 17,000, if bridge openings less than 2 metres are included (Plessias et al., 2019).

2.6 Poland

In Poland according to the Ordinance of the Minister of Development, Labor and Technology of 23 July 2021 on the database of topographical objects and the basic map (Ordinance, 2021) – bridges, viaducts and other engineering objects are registered in this database (Fig. 9), called in short BDOT500. According to paragraph 4 (Ordinance, 2021), the attributes common to all objects of the BDOT500 database are:

- method of obtaining information about the facility;
- the date of admission to the state geodetic and cartographic resource;
- number of the technical report under which the object was entered into the BDOT500 database.

In the category of objects "communication" can be distinguished, among others: OTKM bridge, OTKZ bushing, OTKW Viaduct, OTKE flyover, OTKT track, OTKN platform.

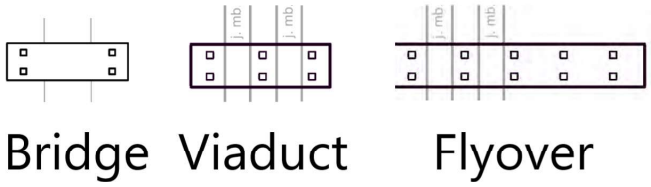

Figure 9: Symbol of bridge and other communication objects on base map and in BDOT500 database (Ordinance, 2021)

Bridges are not registered as objects in the real estate cadastre. The bridge symbol is visible in the BDOT 500 database and on the base map, which contains a cadastral data layer, including boundaries of cadastral parcels. Regardless of registration, In Poland, there is still an old Roman rule related to the perception of the scope of the property right of superficies solo cedit. Art. 46 Civil Code states that, Real estate is the parts of the land which constitute a separate object of ownership (land), as well as buildings permanently attached to the land related or parts of such buildings, if under specific provisions constitute an object of ownership separate from the land. Especially art. 48 states, also that to the part The components of the land include, in particular, buildings and other permanent devices connected with the land. Art. 143 defines the range of property rights. It states that, within the limits defined by the socio-economic land use, land ownership extends to the space above and below its surface. This provision is without prejudice to the provisions governing the rights to water. As a result of such legal and technical solutions, the ground in the plot of land (parcel)

in which a given engineering structure is located, e.g. a bridge, cannot be divided vertically, i.e. in layers.

Pursuant to the Act on Public Roads of March 21, 1985, a road is a structure together with road engineering structures, devices and installations, constituting a technical and operational whole, intended for road traffic, located in the road lane. The bridge structure or tunnel is part of the road and is managed by the road administrator. It should be mentioned that there are bold architectural designs which, in addition to technical barriers, also encounter legal barriers in terms of establishing separate ownership rights in a stratified structure. An example is the museum of Polish history. It would originally be located on a huge platform above the Łazienkowska Route. The museum building would look like a glass bridge.

The draft assumptions of the draft act on separate ownership of buildings construction objects planned in 2010 would legally support the implementation of this type of investment plans. It was mentioned in its content in the section "Current state of social relations in the field of separate ownership of buildings construction".

The Ministry of Infrastructure proposed in 2010 the introduction of a new category of objects that may constitute a separate real estate. The goal of the proposed regulation was to allow for the establishment of separate ownership of objects construction works carried out above or below the ground, not directly related economically with this land property. At the same time, an important premise of the separation of such real estate is the fact that it does not deprive the owner of the rights to the land and does not exclude the possibility of using this land. The subject of separate ownership of construction works was to be in particular: construction works or construction equipment erected above or below public roads, railroads, flowing waters, including buildings, structures, tunnels, viaducts, bridges, overground and underground car parks (see Ministry of Infrastructure (2010)). The draft assumptions of these legal regulations remained at the proposal stage and no similar solutions have been adopted so far.

2.7 Slovenia

As for the registration of land rights for the case of bridges, we must remember the basic legal principle of the Slovenian land administration system, which is "superficies solo cedit". This principle means that ownership of land generally means also ownership of all constructions built-up on the land. Exceptions to this principle are (1) the right of superficies (the right to own a building above or below the land owned by a third person) and (2) apartment ownership (condominium). The right of superficies and condominiums separate the ownership of physical objects from the land itself. For the registration of buildings and parts of buildings, an additional database, i.e. Building Cadastre, was established on the basis of the legislation from 2000, which is linked to Land Cadastre (Pogorelčnik and Korošec, 2001; Drobež et al., 2017). Based on the experience of more than ten years of operational use, the Building Cadastre was partly modified in 2018. The changes concerned the classification of the use of parts of buildings, the submission of digital data and the requirements for geometric data. Regarding the latter, floor plans are now georeferenced and submitted in digital format (GeoJSON), enabling 3D visualisation. It is planned that the Land Cadastre and the Building

Cadastre will be merged into a single Real Property cadastre by 2022 (Real Estate Cadastre Act, 2021).

However, these two rights have been introduced for buildings and not for other construction objects, such as bridges. Following the principle “superficies solo cedit”, the ownership of bridges “share” the same ownership of land under the bridge. The legal solution on how to protect the rights of the objects of (public) infrastructure has been the topic of several professional and political debates in the last two decades. The Surveying and Mapping Authority established a database on public infrastructure, i.e. Cadastre of Public Infrastructure, that was designed in 2004. The main purpose has been to provide the state, local communities and other users with the georeferenced data on public infrastructure in a centralised and standardised way. An additional aim was to prepare a reliable database on public infrastructure to support the registration of rights, restrictions and responsibilities on the objects of the public infrastructure. However, this legal challenge has not been solved yet.

Focusing on bridges, several approaches can be found in practice. In particular, in the case of “water land”, which is, according to the Slovenian legislation, a public good, the ownership of the land cannot be changed, and the bridge is officially owned by the state. In the case of new bridges/viaducts, where private or public land is beneath the bridge, there are two main practices (i) the investor buys the land under construction or (ii) easements are registered in the land registry for land parcels and parts of land parcels that are under construction. These approaches are then reflected also in the land parcel structure (Fig. 10, Fig. 11).

Figure 10: Land parcel structure for the case of bridge: land parcel boundaries (green) and boundaries of cadastral municipalities (red) on state orthophoto (Surveying and Mapping Agency of the Republic of Slovenia)

Figure 11: Land parcel structure as presented in the field book on land subdivision from 2012 (Surveying and Mapping Agency of the Republic of Slovenia)

In addition, the solutions regarding the land ownership registration for land under bridges might also vary in terms of their heights above the ground. Bridges may be close to the surface, but there are also cases where a maximum height above ground is more than 50 m. In these cases, the practice varies as well. In the case of acquisition of land for this infrastructure object, this is reflected in land parcel structure, while in the case of an easement, this right/restriction is only registered in the Land Registry at the court. The new legislation from 2021 has foreseen that the spatial extension of easements should also be registered in the land cadastre as part of land parcel(s).

2.8 Sweden

The possibility of forming 3D property units was introduced in 2004, as an addition to existing 2D property formation (SFS, 1970). One purpose for this new type of property was the implementation of major infrastructure projects, which was specified as a need for the introduction of 3D property formation (Eriksson, 2005, p. 12).

The traditional 2D property has no fixed delimitation of the property volume above or below the ground surface, and it is possible for the property owner to construct infrastructure facilities above or below ground within the property volume. Constructing such facilities can also be done by another party, with the consent of the owner or through expropriation means if there is no consent, normally providing compensation for the take.

During the investigations before the 3D property legislation was introduced, 3D property formation was considered a valuable tool for solving complicated problems within building projects and for various purposes (Proposition 2002/03:116, pp. 31-32). Among the purposes mentioned were 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.

The Swedish 3D property is defined as a property unit, which in its entirety is delimited both horizontally and vertically (SFS, 1970, Chap. 1, s. 1a). The 3D property may also extend over or under several ground parcels, and is thus not bound to be located within one two-dimensionally delimited property unit. In the regulations of the 3D property formation, it is prescribed that 3D property formation is only allowed if the 3D property accommodates, or is intended to accommodate, some kind of construction, such as a building or other facility or a part of the same. However, there are no specific regulations regarding where the boundaries surrounding the 3D property unit should be drawn. This is rather decided in the specific case, although recommendations are provided for. The recommendations (Lantmäteriet, 2003), however, provide that there is no need for the boundaries to exactly follow the delimiting area of the construction, but can include some volume of space for protruding parts, use and management. It is also possible to include in the 3D property unit a larger volume around the facility in order for it to be used for its purpose and to accommodate everything needed for its operation. This is the case for e.g. bridges and viaducts. The recommendations (Lantmäteriet, 2003) also give the possibility to include a protective area around the facility within the 3D property unit, in order to prevent damage by surrounding properties or for management purposes. Another possibility is to create a 3D easement as a protective volume, but included in the surrounding property unit.

The 3D property units are registered in the cadastral index map as part of the national Real Property Register, as well as in the textual part of the register (Lantmäteriet, 2004). For each 3D property unit, the type of space is also indicated, of which 'bridge' is one such type. Today, in total 15 3D property units are registered with the purpose "bridge" in the real property register. However, there are no bridges or other such constructions that constitute pure 3D property units, although they are facilities that are connected with traditional 3D property units. For facilities in the air that lack contact with the ground, such as bridges or viaducts, the vertical location should be specified in the form of coordinates or measurements, in addition to maps and textual descriptions to show the location of the 3D property unit (Lantmäteriet, 2003). The register also indicates the traditional 2D property units within the volume of which the 3D property unit is located.

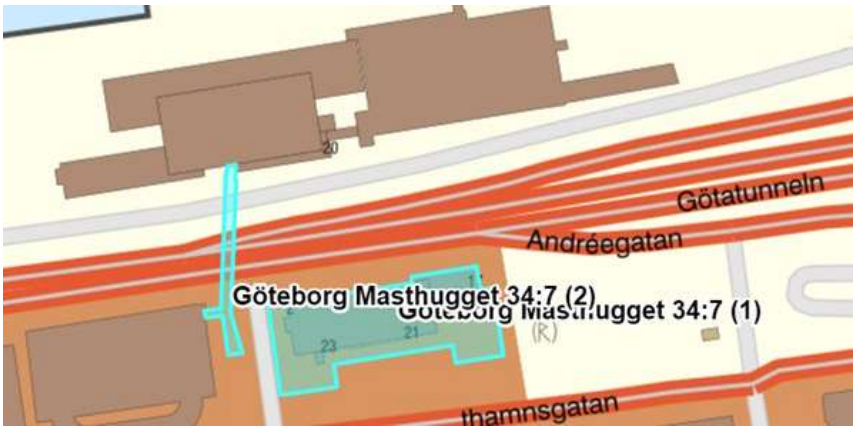

Figure 12. Example showing a 3D real property consisting of two parts. The left part, no 34:7 (2), is a bridge. Extract from the Swedish Digital Index Map. Lantmäteriet, The Swedish mapping, cadastral and land registration authority.

3. DISCUSSION ON LESSONS LEARNED FROM THE EXAMPLES AND CONCLUSIONS

This work examines the approaches regarding legislation and registration of 3D infrastructure objects, especially bridges and viaducts, in 8 European countries. All examined countries are based on the Civil Law legal tradition, specifically the Scandinavian and the Germanic Civil Law. Among the examined countries, Sweden has an operational 3D cadastral system, where 3D real property units can be established, while the rest operate under the Roman principles on the extent and the content of real property ownership. The downside in Sweden is the slightly increased effort during preparation for the registration.

Apart from the Swedish case approach that was developed considering the implementation of infrastructure objects, the rest of the examined countries implement different solutions. Similarities can be traced partially between different aspects of registration. For example, specific annotations used in Croatia are close to the tag concept that applies, in several cases, in Greece. At the same time, the representation of bridges without being officially registered can be traced in several cases both in Bulgaria and Czechia, often also in Slovenia. The easement/servitude solution is a concept shared by Austria and Slovenia.

However, there are three countries that have been motivated to modify their legal framework due to the limitations deriving from the overlapping rights of private and public rights in case of major infrastructures (Greece, Poland and Slovenia), ranging from discussions on technical level for cadastral survey requirements (Greece), (not yet implemented) legal proposals (Poland) and new legislation (Slovenia – cadastral registration of easiments).

On the other hand, the Swedish system of 3D real property units provides already 15 cases of bridges established exploiting the 3D real property unit concept, while also providing other three-dimensional solutions for the construction and maintenance of major developments (e.g. 3D easements). Although the Swedish solution is the most innovative and is based on well-established cadastral procedures among the examined countries, the limited number of 3D real property units used within a period of 17 years after the introduction of 3D property units needs to be considered for further communication of the 3D real property unit concept and the capitalisation of its merits.

It is obvious from the national cases, that the Roman principle superficies solo cedit still affects the legislation in many European countries (e.g., Austria, Slovenia, and Poland). This principle has benefits in case of low construction density, when a 2D representation is sufficient. Then it provides simple rules and leads to legal security. However, when vertical separation becomes relevant, the principle creates problems. Several solutions have been implemented for bridges:

- Do not document them at all
- Document them in a register outside the cadaster
- Show them in the cadaster as additional information but not as cadastral objects
- Show them as separate land use
- Register them as easements

A problem with these solutions is that detailed regulations on responsibilities might not be part of the cadastral description but stored in separate documents. These documents may be difficult to acquire even if geometrical, technical, and legal data are in principle publicly accessible as shown by the Austrian example. The Swedish cadastre is the farthest among the investigated countries in the development of 3D cadastral structures, such as the surveying effort. The advantage is obviously the easier registration of rights, restrictions, and responsibilities, because there are well defined objects that they are attached to. This leads to simpler decision making in case of dispute. The downside is the increased effort during preparation for the registration.

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BIOGRAPHICAL NOTES

Marcin Karabin Ph.D., D.Sc. Professor at Warsaw university of Technology. Born in Warsaw in 1976. Studies of Geodesy and Cartography at the Warsaw University of Technology. Graduated his (M.Sc.) in Geodesy in 2000. Ph.D. in 2005, at the Warsaw University of Technology, D.Sc. 2014 at the Warsaw University of Technology). Licensed surveyor since 2006. Has professional license in the field of: „Land Surveying, implementation and inventory surveys" and "Delimitation and division of real estates (plots) and preparation of documentation for legal purposes". Current position: Professor at the Warsaw University of Technology (Department of Cadastre and Land Management, Faculty of Geodesy and Cartography), also providing surveying services as a licensed surveyor (since 2006).

CONTACTS

Marcin Karabin
Warsaw University of Technology,
Department of Cadastre and Land Management
Plac Politechniki 1
00-661 Warsaw, POLAND
Mob.: +48-608-402-505
E-mail: Marcin.karabin@pw.edu.pl

Dimitrios Kitsakis
National Technical University of Athens
School of Rural & Surveying Engineering
125, Char. Trikoupi str.
11473, Athens, GREECE
Phone: +306949725897
E-mail: dimskit@yahoo.gr

Mila Koeva
University of Twente (ITC)
Hengelosestraat 99
7514 AE Enschede, THE NETHERLANDS
Phone: +31 (0)53 487 44 44
Fax: +31 (0)53 487 44 00
E-mail: m.n.koeva@utwente.nl

Gerhard Navratil
TU Wien
Gusshausstr. 27-29/E120.2
Vienna, AUSTRIA
Phone: + 43 1 58801 12712
Fax: + 43 1 58801 12799
E-mail: gerhard.navratil@geo.tuwien.ac.at
Website: https://geo.tuwien.ac.at

Jesper M. Paasch
University of Gävle & Lantmäteriet
The Swedish mapping, cadastral and land registration authority
80182 Gävle, SWEDEN
Phone: +4626633001
E-mail: jesper.paasch@lm.se

Jenny Paulsson
KTH Royal Institute of Technology
Real Estate Planning and Land Law

Teknikringen 10B
10044 Stockholm, SWEDEN
Phone: +4687906661
E-mail: jenny.paulsson@abe.kth.se

Nikola Vučić
State Geodetic Administration,
Gruška 20
Zagreb, CROATIA
Phone: +385 1 6165 439
E-mail: nikola.vucic@dgu.hr

Karel Janečka
University of West Bohemia
Technická 8
Pilsen, CZECH REPUBLIC
Phone: + 420 607982581
E-mail: kjanecka@kgm.zcu.cz
Website: http://gis.zcu.cz

Anka LISEC
University of Ljubljana
Jamova cesta 2,
1000 Ljubljana, SLOVENIA
Phone: +38614768560
E-mail: anka.lisec@fgg.uni-lj.si