

VZPOSTAVITEV SODOBNEGA KATASTRA: PRAVNI VIDIK OPISOVANJA NEPREMIČNINE V TREH RAZSEŽNOSTIH

BUILDING A MODERN CADASTRE: LEGAL ISSUES IN DESCRIBING REAL PROPERTY IN 3D

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IZVLEČEK

Obravnava nepremičnin v treh razsežnostih (3D) je postala pomembna raziskovalna tema v preteklem desetletju. V prispevku so predstavljene ugotovitve in nadaljevanje mednarodne razprave o pravnem vidiku evidentiranja nepremičnin v treh razsežnostih, ki je potekala na četrti mednarodni delavnici o 3D-katastru leta 2014 v Dubaju. Namen prispevka je nadgraditi in analizirati pravne vidike trirazsežne nepremičnine ter predstaviti izkušnje na področju določevanja in registracije 3D-nepremičnin. Vzpodbuditi želimo nadaljnjo razpravo o pravnih okvirjih uveljavitve koncepta 3D-nepremičnine in 3D-katastra, predvsem pa pri tem določiti ključne vsebine pri obravnavanju pravnega vidika tega vprašanja.

ABSTRACT

Three-dimensional (3D) real property has been the subject of increased research activity during the last decade. This article continues the discussions of the legal framework sessions at the 4th international workshop on 3D cadastres in Dubai 2014 in order to further develop and analyse the legal concepts of 3D real property, and presents an overview of experiences from 3D property use and registration. The outcome is intended to initiate discussions on the legal framework of 3D cadastres and aims at identifying the main topics concerning the legal aspects of 3D property and cadastre.

KLJUČNE BESEDE

3D-kataster, 3D-nepremičnina, pravni okvir, upravljanje zemljišč

KEY WORDS

3D cadastre, 3D real property, legal framework, land management

1 INTRODUCTION

As humans we live in a three-dimensional (3D) world. All processes are implemented and experienced in a 3D environment; from agriculture to navigation, from recreation to consumption. We use the space for e.g. apartments and offices, and implicitly attach ownership rights and rights of use to these spaces and objects. Legislation traditionally addressed real property as two-dimensional (2D), only implying limited or ambiguous vertical aspects depending on each case. As needs of modern societies on land increased, further limitations were required to regulate overlapping private and public rights. Such complex cases cannot be accommodated through current legislation, which was based on the assumption that overlapping rights could be addressed through instruments such as condominiums, limited real rights or specific legislation.

The documentation of the legal situation for rights on real property, however, is traditionally done in 2D. The reason is that 3D models were expensive to build and difficult to store. It was computers with 3D visualization capabilities that changed the situation and allowed the use of real 3D models for design, visualization, documentation, and analysis. Since most land right documentation systems were introduced before computers were even developed, traditionally rights are documented in the horizontal plane only and seen as vertically unrestricted. This obviously collides with the observation of a 3D reality, so the shift from 2D to 3D documentation is reasonable.

Ploeger (2011) argues that *“if a legal system does not provide the instruments to create 3D property, there is no need for a 3D cadastre at all.”* In addition, a 3D cadastre itself does not make 3D property rights possible. The term 3D property is much used in connection with three-dimensional objects such as apartments/condominiums in (often multi-floor) buildings and other physical constructions such as underground garages and tunnels. Nevertheless, the foundation for managing physical facilities is the legal framework(s) which define the rules for e.g. RRRs (rights, restrictions and responsibilities) in three dimensions. When developing and using a successful and lasting system for 3D property rights, there are certain key factors that seem to be of particular importance regardless of legal system, several of which are related to management (Paulsson, 2007). There have to be clear rules regarding this management of 3D property included in the legal framework of 3D property rights. The concepts of 3D property formation and management are for example used to secure and describe ownership and other rights in densely populated urban areas, thus making it possible to establish real properties and other RRRs “on top” of each other, thereby creating a framework for a more effective management and use of space in three dimensions.

Although 3D property has a foundation in legislation, the authors have noted a tendency to focus on non-legal, e.g. technical, questions in 3D property research rather than on legal issues, which are the basis of 3D property. This observation is supported by the discussions during the 2nd and 4th international workshops on 3D cadastre (Banut, 2011, pp. 3–4; Paasch, 2014), which both resulted in conclusions that further research on the legal aspects is required. The 4th workshop discussions were based on a position paper aiming at initiating the discussions of 3D legal frameworks by identifying the main topics concerning the legal aspects of 3D cadastre (Paasch and Paulsson, 2014). The paper initiated discussions on the legal framework of 3D cadastres and aimed at identifying the main topics concerning the legal aspects of 3D cadastre and further future research.

2 PROBLEM DESCRIPTION AND AIM

Several problems in the use of 3D property today from a legal point of view have previously been identified. Ho et al. (2013) mention, among others, the concept of 3D property, its legal status and classification of associated rights; questions raised over the legislative framework required to support autonomous registration of 3D property, common property regimes, and the registration of real property vs. physical objects. Ho et al. (2013) point out that the literature on legal issues in this field has to a large extent been focusing on the actual concept of 3D property and refers e.g. to different types and categories of 3D property (see Paulsson, 2007). They point to the lack of progress towards implementation of 3D cadastre as resting mainly on legal limitations. That is why this article is focusing more on other issues related to implementation of a 3D cadastre rather than discussing the concept of 3D property.

Other examples illustrating the need for research on 3D property have been described in Paulsson and Paasch (2013), Paasch (2014), and Paasch and Paulsson (2014). The outcome of the legal framework working sessions (Paasch, 2014) showed several areas in which 3D legal research could be improved, e.g. illustration of the benefits in describing and securing real property through the introduction of 3D real property concepts, restrictions and responsibilities affecting land use. The workshop also concluded that comparative studies on the use of 3D property concepts are a valuable input for understanding other legal systems and receive input for e.g. further development of one's own legal system(s).

A land right documentation system consists of definitions, documentation, and processes. The required processes are the same as for any documentation system: Data needs to be created, changed, deleted, and retrieved (Navratil and Frank, 2004). These processes may not require much change. However, the data itself, i.e., the documentation, and the definition of the elements need to be addressed when moving from 2D to 3D.

Definition of legal attributes is also complex. Changes in the definition are necessary and a typical change is the term of the range of property rights (compare Acharya, 2011; Erba and Graciani, 2011; Dimopoulou and Elia, 2012; Karabin, 2014). There may be regional similarities, but each country has its own legal framework, constitutional definitions, and legal traditions. Definitions developed for one country may not be applicable in any other jurisdiction. It needs to be analysed what parts of a legal setup can be transferred to another country and what parts need to be adapted. This would require a common terminology that is still lacking (Ploeger, 2011). Any technically sound solution could be implemented. The solutions for one country can be used as starting points for the development of solutions in other countries and thus countries can learn from others' experiences and avoid their implementation errors.

This article continues the discussions of the legal framework sessions at the 4th international workshop on 3D cadastres in Dubai 2014 in order to further develop and analyse identified research issues relating to the legal concepts of 3D real property, and presents an overview of experiences from 3D property use and registration. The outcome is, however, not intended to present a comparison of national 3D solutions, but to initiate discussions on the legal framework of 3D cadastres and aims at identifying the main topics concerning the legal aspects of 3D property and cadastre, as well as needs and possibilities for further future research (Paasch, 2014). These legal aspects are categorized below as the legal difference between 2D and 3D; ownership rights and building (use) rights; and cost and value of 3D cadastral processes.

3 LEGAL ASPECTS OF 3D REAL PROPERTY

The legal definition of real property worldwide is, in most cases, based on the Roman principles comprising vertical accession and land extents from the centre of the earth up to the sky. Such principles are either applied in a more flexible way facilitating real property stratification, e.g. Common Law jurisdictions, or in a more restrictive way, e.g. in Civil Law jurisdictions (Kitsakis and Dimopoulou, 2013). While old, the concept is still in use in many modern jurisdictions (compare Ball, 1928; Dale and McLaughlin, 1988, p. 20; Ellickson, 1993, p. 1363). Ellickson uses the example of mining activities to motivate the necessity for vertical boundaries, i.e., a separation of ownership of the land from the ownership on the mineral resources. He also points out that mining activities are typically undertaken on larger areas than other types of land use like agriculture or housing (Ellickson, 1993, p. 1363). However, the focus here is on the simplicity of rules as the “creation of a new vertical boundary is administratively burdensome and invites conflicts between owners of adjoining layers” (Ellickson, 1993, p. 1364). Thus 3D property is less a problem of legal definition and more a problem of delineation.

Establishment of 3D Cadastres does not imply the introduction of a radically different land management system. Its aim is identical to that of a traditional cadastre: to provide legal security on rights, restrictions, and responsibilities (RRRs) imposed on land by representing it on a map. However, it is able to cope with more complex RRRs and can represent their spatial extent more clearly. Given the diversities of national legal systems, there is no unique 3D Cadastre solution that is pursued. Implementation of general concepts of land management in 3D would be sufficient, if adapted to national legal peculiarities. These concepts include legal definition and establishment of 3D real property units that are unambiguously delimited in 3D space, along with necessary tools of management of such 3D objects. Furthermore, adjustment of Public Law regulations to 3D reality is required to support efficient land management. Organisational and technical aspects should also be considered within the, pursued, 3D cadastral framework; cadastral laws should be amended accordingly to support 3D cadastral survey along with cadastral databases to record and present real property data in 3D.

Looking through lawyers' participation in 3D Cadastre Workshops, it seems that their interest in the legal aspects of 3D Cadastre is not great; as noticed during the 4th Workshop on 3D Cadastres, no lawyers attended (Paasch, 2014). Furthermore, property laws are well established and not easily reformed, reflecting social and cultural peculiarities of each jurisdiction (Ho et al., 2013). However, there are still legal issues that need attention. We pinpoint some of them in the continuation.

3.1 Is there a legal difference between 2D and 3D?

2D and 3D parcels are not much different: A parcel is an n -dimensional subspace in n -dimensional space. Whether it is modelled as a 2D space or a 3D space is irrelevant. The concept of neighbours exists in a 2D system as well as in a 3D system. However, there are different kinds of legal dependencies between neighbouring parcels. Whereas in 2D, aspects like water runoff or physical access are easy to model and solve, physical dependencies in 3D situations are much more complex. A multi-storey building is constructed in a way that the weight of the upper levels is supported by the lower levels. This physical dependency translates into ownership restrictions if the condominium rights are defined as 3D parcels (Navratil, 2012). This relation is new and although it may be treated like other relations, legal experts must analyse it for possible effects. The same may be true for other relations that are connected to 3D, such as the ownership of walls between apartments or maintenance rules for common staircases and building infrastructure.

Land seems to share similar definitions both in Civil and Common Law jurisdictions. Civil Law defines real property to be extending to the space above and below the surface parcel, comprising all buildings and constructions permanently attached to it. However, the real property extent is either delimited to the extent that the owner has “no interest in opposing against it”, (the expression “as far as the owner has any practical interest” is also used) or it is subject to laws referring to mines, water, environment, archaeology, urban planning and aviation. Explicit reference to individual stratified property is e.g. made to Swedish Land Code defining that real property can be delimited either horizontally or both horizontally and vertically (Chapter 1, Sec. 1). Similarly applies to the Cadastre Act of Norway that provides for 3D parcels along with limitations on cadastral parcels due to “possible creation of 3D parcels” (Chapter 2, Sec. 5). Latin American “(legal) land objects” may also be considered as a kind of 3D concept, although, except for Argentina, are not explicitly defined in Latin American countries’ legislation (Erba and Piumetto, 2012). In Common Law “land” is commonly defined as “...land, messuages, tenements, hereditaments, corporeal and incorporeal, of every kind and description, whatever the estate or interest therein, together with all paths, passages, ways, watercourses, liberties, privileges, and easements appertaining thereto, and all trees and timber thereon, and all mines, minerals and quarries, unless specially excepted...” (stipulation used in Transfer Land Act of New Zealand, Land Titles Act of Alberta, Real Property Act of Manitoba).

Terminology describing 3D property internationally along with legal definitions differs (Paulsson and Paasch, 2013). Independent 3D property units may be defined as “volumetric parcels (or spaces)” situated above and/ or below land surface, that may or may not be partially or totally occupied by a structure. Australian states and New Zealand definitions of 3D property focus on horizontal and vertical delimitation of land in height and depth; a similar concept applies to Swedish and Norwegian legislation while in Israel, subdivision of surface parcels to spatial sub-parcels has been selected after a research and development project to register rights in space (Benhamu, et al., 2005) although relative legislation has not yet been established. A more complex concept of real property units with 3D aspects applies in Malaysia, including accessory units, parcel units, limited common property and land parcels (Zulkifli, et al., 2014). Depending on intended use of 3D property, some countries have introduced different types of 3D units, such as the three-dimensional property unit and three-dimensional space in Sweden, or the standard, volumetric, restricted and remainder parcels in the state of Queensland (Paulsson, 2012; Land Act of Queensland).

3.2 Ownership rights and building (use) rights

Definition of real property by law comprises everything that is permanently attached to land, i.e. the “*superficies solo cedit*” principle. Consequently, real property ownership has been strongly related to building rights. Such a concept could not accommodate vertical real property exploitation involving overlapping rights, which has led to the introduction of limited real rights or other laws establishing horizontal property or posing restrictions on real property’s vertical extent, aiming to dissociate building and use rights from land property rights (Monteiro, 2008). 3D Cadastre legislation would allow for such a distinction and secure proper exploitation of real property within the land market.

Furthermore, 3D Cadastre legislation provides the opportunity for exceptional real property regimes with 3D aspects to be incorporated in cadastral databases so that such rights are properly described and secured. Characteristic examples are Special Real Property Objects, SRPO, e.g. in Greece where land

ownership and building rights do not coincide and e.g. public properties located below private properties, see Figure 1, or building rights in Brazil, where land is owned by the surface parcel owner, while the air in which buildings stand belongs to the State (Erba and Piumetto, 2012).

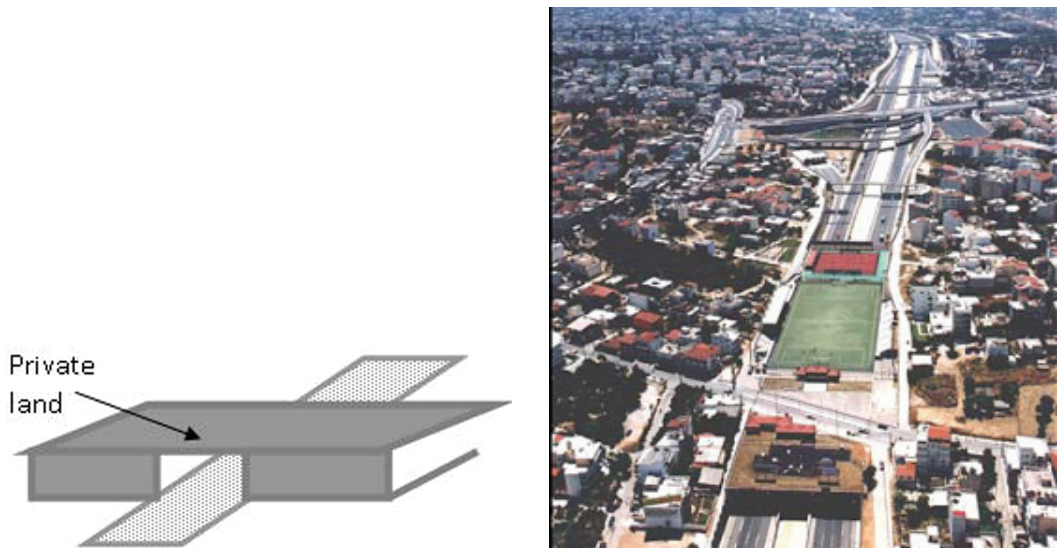


Figure 1: Sports facilities situated above a major public road (Dimopoulou et al., 2006).

Similarly applies in case of utility easements for the establishment and maintenance of underground utilities, where ownership of the surface land parcel may not imply respective building rights, due to restrictions posed by the exercise of the easement. Public Law regulations may also result in differentiation between land ownership and building or use rights that fall in 3D Cadastre legislation scope; within a 3D cadastral legal framework, such differences are easier to be established, recorded to cadastral databases, presented on cadastral maps and managed. An example of 3D subdivision of a building creating separate ownership rights for horizontal properties can be seen in Figure 2.

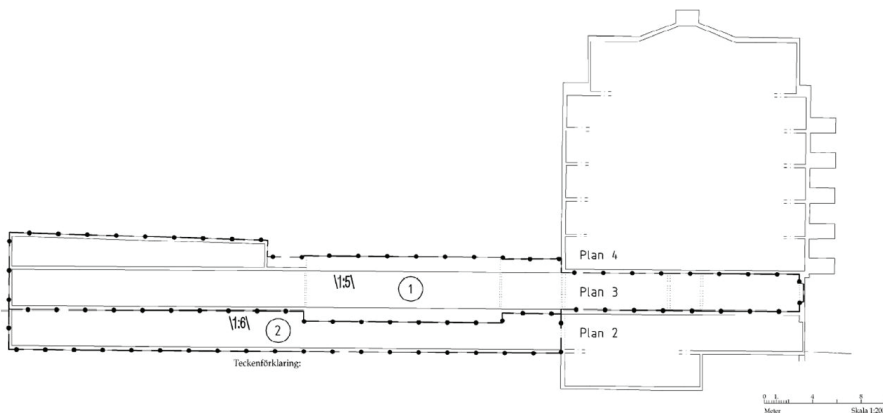


Figure 2: Example of 3D subdivision of a building creating separate ownership rights for horizontal properties: Offices (Plan 2), parking facilities (Plan 3) and dwelling purposes (Plan 4). Source: Lantmäteriet, the Swedish mapping, cadastral and land registration authority.

Building rights are difficult to manage in traditional 2D cadastral systems. An example is the Austrian cadastre, which is well-developed and provides the concept of building right. The land owner grants the right to build on his/her land and during the legal existence of the right (which is restricted to 99 years), the beneficiary of the building right is the owner of the building. This includes the right to use the land in a required extent. This implies using the path from the building to public land. However, the right holder may be entitled to use the complete parcel or at least parts of it. The actual spatial extent and the included rights (e.g., plant trees or pave the path to the house) are part of the building right contract. However, the cadastral map does not show the spatial extent and the land register does not show the included rights. Figure 3 shows the missing representation of the geographic extends in the cadastral map. Although the construction is situated in the southern part only, the cadastre does not indicate any restriction.

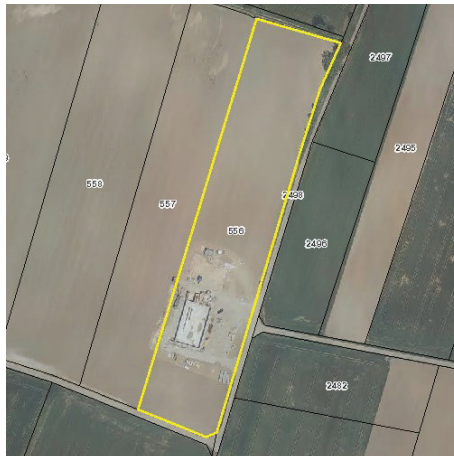


Figure 3. Example of a building right in the Austrian cadastral map. Source: BEV, Federal Office of Metrology and Surveying, Republic of Austria.

3D ownership and building rights may be subject for rather rudimentary descriptions in a nation's cadastre. For example, the registration of a Swedish 3D property is done by registration of textual information in the textual part of the cadastre, and by registration of contour footprints in the cadastral index map. The spatial representation of 3D property in the cadastral index map is sometimes also quite rudimentary. See Figure 4 and 5.

Läge, karta (09)				
Område	N, E (SWEREF 99 TM)		N, E (SWEREF 99 18 00)	
1	6582728.4	671911.8	6581457.7	151337.1
2 3D-utrymme	6582787.6	672177.9	6581504.8	151605.6
Ändamål: byggnad				
Storlek: Utrymmet i horisontalplan är ca 75 kvm.				
Höjd: Höjdläget är mellan CA+31,2 meter och CA+55 meter i RH00.				
Urholkar: Solna Haga 4:20, Solna Haga 4:26				
3 3D-utrymme	6582888.3	672049.6	6581611.2	151481.9
Ändamål: byggnad				
Storlek: Utrymmet i horisontalplan är ca 6 kvm.				
Höjd: Höjdläget är mellan CA+26,3 meter och CA+58,5 meter i RH00.				
Urholkar: Solna Haga 4:20				
Urholkas av				
3D-utrymme: Solna Haga 6:1 område 1				

Figure 4: Registration of textual 3D property information in the Swedish cadastre, marked by red circles. Extract from the Swedish real property register. Source: Lantmäteriet, the Swedish mapping, cadastral and land registration authority.

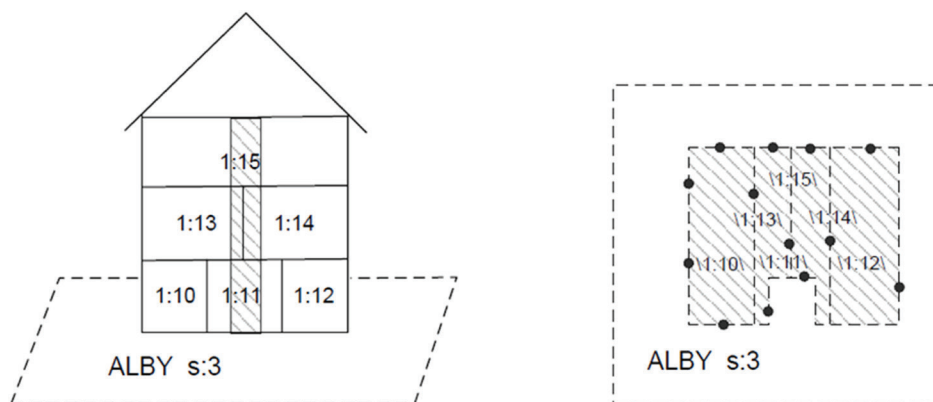


Figure 5: Registration of spatial 3D property information (left) in the Swedish cadastral index map (right). Lantmäteriet (2004).

Similarly, in Croatia ownership rights in the form of separating special parts of a real property unit can be modelled as integral parts of a 3D building model (Figure 6) and during that process a unique identifier of special part of a real property can be assigned to an apartment or an office space within each building (Vučić et al., 2013). Attributes which can be registered for special part of a real property, and can be potentially important, are 3D coordinates, plan area and volume (which are calculated by 3D coordinates), orientation of special part of a real property, the use (for example apartment, a suite, an office space, etc.), the number of floors in a building, the year in which the building was built etc. That means everything that is necessary for the country as the founder and owner of the official register, having in mind the needs of potential users of that register, the needs of the country itself and the economic progress and legal security which is expected out of an official real property register.



Figure 6: A special part of real property.

A unique feature identifier can be assembled by using the identification number of the municipality, the number of a building in a cadastral municipality, floor (where underground partitions are identified as P-1 until P-n, ground floor as P, and over-ground partitions as P+1 until P+n) and in the end the number of the special part of a real property on an individual floor. As an example a building was chosen at address Zagreb, Trnsko 12, an apartment on the 10th floor (Table 1).

Table 1: An example of forming a unique identifier of a special part of real property

Identification number of a cadastral municipality	Number of building in cadastral municipality	Floor	Number of a special part of real property
335444	55	P+10	4
Unique feature identifier = 335444,55,P+10,4			

3.3 Cost and value of 3D cadastral processes

The success of a cadastral system is not dependent on its legal or technical sophistication, but whether it protects land rights adequately and permits those rights to be traded (where appropriate) efficiently, simply, quickly, securely and at low cost. The Bogor Declaration identifies, among others, the following key issues: clear identification and recording of ownership rights and restrictions and obligations to land, speed and keeping up-to-date (UN-FIG 1996). 3D cadastres aim at improving the first part by providing better spatial delimitation of rights. However, if the available (financial) resources are insufficient to keep an existing, traditional cadastral system up-to-date then there is a need for economic justification. Protection of rights and restrictions in 3D cadastres is identical to the protection in 2D systems and needed in both cases. The description of real property in 3D is considered to be more complex, though, and influences existing formalities such as subdivision, conveyance, mortgage and management of real property. This may cause higher costs for changes in the data. These costs must be justified by added value for the right holders.

However, these concerns do not reflect the practical benefits that could be reaped through 3D cadastral legislation. Feder and Feeny (1991) present the way land rights impact on the incentives and scope of land market transactions in land and credit, including provision of incentives to efficient land use and investment, reduction of uncertainty and credit market efficiency. Establishment of 3D land rights practically generates “new”, legally secure, property units that can be exploited with similar effects to land rights in contemporary 2D real property. Possibility of 3D property segmentation would allow for more space to be available on the land market that allows reduction of acquisition costs and therefore, a more attractive concept for investment projects.

Use of 3D property as collateral for financial credit would be of benefit both for financial institutions and the borrowers. 3D rights secure 3D real property, reducing the risk of financial institutions to provide funding, which, consequently, facilitates financing of investment projects. Proper implementation of such a concept would require to be combined with the development of 3D Public Law and any other regulations, ensuring timely update of the Public Registers so that no 3D units that are encumbered by 3D restrictions can be used as collateral. Given that restrictions on real property do not always imply preventions of using real property as collateral, legislation would also be required to define the cases where 3D restrictions on real property comply with the establishment of collateral relationships.

The introduction of 3D cadastral parcels would result - the case of many investments - in the lack of a necessity to purchase the property rights to "entire" cadastral parcels, as it happens in the case of the two-dimensional cadastre (Karabin, 2014). Many types of aboveground and underground objects like tunnels of underground railways, railway tunnels, overpasses or underground parking places in 2D cadastre are established in a way of setting a servitude. A servitude right is not an attractive form for investors, because the lack of possibility to set a mortgage based on this right. Conversion of servitude based investment into ownership right based investment is a qualitative step. Ownership right provides full security for the owner and gives the possibility to credit the investment based on the ownership right. 3D cadastral parcels would also allow economical use of compulsory purchase because it allows to restrict the deprivation of ownership to the minimum amount of space.

Another benefit of introduction of 3D cadastral legislation in case of underground infrastructure can be the disengagement from real property expropriation or obligatory utility servitudes' establishment for reasons of public benefit, which requires issuing of an implementing Act or ministerial order or decree. Relative volumes of real property could be conveyed from the surface parcel owner to the agency responsible for infrastructure's establishment, minimizing time costs and offering full ownership of the relative volumes. In general, all kinds of vertical restrictions or responsibilities on real property originating from Public Law, in most cases non parcel based, can be taken into account. Such regulations have an impact on the exploitation of real property; definition of the exact extent of Public Law regulations within 3D Cadastre would prevent encumbering of the whole real property, but only of specific volumes where such regulations apply and at the same time improve the transparency by making the restriction visible.

Furthermore, the vertical extent of each of these rights is in most cases described literally and is not defined using height reference systems or vertical coordinates, which can lead to disputes and uncertainties between overlapping rights' owners. Additionally, as overlapping ownership may be established through different limited real rights, the association of the authorities, deriving from such rights, between different owners becomes a complicated task. Rights, restrictions and responsibilities on land defined in 3D do not imply ambiguities concerning their extents, can be surveyed and recorded in public registers and, therefore, are more secure over "traditional" 2D descriptions of real property.

Existing concepts of real property stratification such as limited real rights, or indirect ownership, provide inferior legal safeguards to real property and the authority of their holder on land is defined by his/her contractual agreement with the landowner or it is subject to Civil Code or relative laws on real property. This means that he/she cannot freely exploit real property but only within the aforementioned limits which makes such rights less attractive to be used for investments (Ekbäck, 2011).

Description of real property in 3D also allows for more efficient exploitation of real property as the restrictions posed by surface parcel's indivisibility and limited real rights or other stratification alternatives' drawbacks could be prevented. Similarly, in case that only a volumetric part of the real property is required for exploitation, it allows "extraction" of the specific real property volume instead of the whole of the real property itself. A characteristic relative example is presented by Sandberg (2003) concerning the Akunas case where expropriation of volumes under privately owned land was required in order to construct a tunnel.

4 DISCUSSION AND CONCLUSIONS

From the above it is evident that the topics discussed in the legal framework working sessions are still relevant. The workshop concluded that comparative studies on the use of 3D property concepts are a valuable input for understanding other legal systems and receiving input for e.g. further development of one's own legal system(s). General issues that have been discussed in this article are important to consider in relation to 3D property.

The selection of the aforementioned topics was based on justifying the necessity of 3D cadastral legislation compared to conventional 2D. Therefore, the analysis was initiated by presenting why and how 3D property is differentiated from 2D property and examined whether these types of property are the same.

From the studies the importance of legal aspects of 3D cadastre is evident and we believe that research towards this direction should be continued and promoted. Not only researchers should continue this important task, but also legal professionals should be motivated to participate in 3D cadastre research, using an interdisciplinary approach.

As we can see from previous studies, 3D property is differently perceived worldwide, which means that comparative studies should take into account differentiations in national legislation. It also means that the 3D property concepts should be clarified concerning the terminology that is used and the fields of application. In this way 3D property should become familiar to the public and professionals instead of being a complicating factor in real property management.

The discussions at the 3D Cadastre Workshop started from the ideas summarized by Paasch and Paulsson (2014). Questions like the difference between 2D and 3D were a direct result from these discussions. What was missing is an overview on different approaches used in different countries. These approaches comprise legal concepts and organisational issues, and economic benefits. One of the observations at the workshop was the absence of legal experts. It seems that the topic of 3D cadastre is of no real interest for them. Much legal research is done as soon as conflicts arise. These may be conflicting concepts between laws (e.g. data preservation law vs. privacy) or between persons. Since there are not many registered 3D property objects, no boundary conflicts happened yet. The authors assume that more legal interest will be observed when the first boundary disputes between 3D property objects are brought to court.

5 FURTHER RESEARCH

This research has shown that interconnection between technical and administrative structures of Land Administration Systems are of importance for achieving an effective 3D Cadastre. We are beyond the time where "land register" and "maps" are treated as separate entities. Further research could support developing effective land management systems that are able to manage both spatial and textual 3D components, regardless of information being stored in single or multiple databases.

Another research issue is how concepts of (formal) 3D property may be used to ensure informal and/or customary ownership and use rights in three dimensions. An example is the Social Tenure Domain Model (FIG 2010), which has gained much interest in recent years as a tool for securing rights, e.g. in developing countries.

The interrelation between legal and economic aspects of 3D property concepts should also be given more attention in future research. Examples of questions to be investigated are: 1) how the implementation of a national legal framework allowing the creation of 3D property formation would influence property values; and 2) how 3D property would influence the pricing level of local property markets, compared to the use of outer means of securing ownership and use rights in three dimensions, such as joint tenant ownership where the tenants are co-owners of a building and are provided a right to live in a specified apartment.

The concepts of 3D property formation and management must also be developed in rural areas, e.g. for registration of mineral rights in mining areas, since these fields are not properly explored yet. Another issue to further investigate is how legislation could be adjusted to 3D reality in terms of Public Law Regulations, that affect land management to a significant extent while it is important to achieve an increased knowledge of 3D legal concepts among the public and professionals.

The legal definitions of land ownership vary between countries. Some countries do not have land ownership at all, others are based on Germanic or Roman law or on other legal traditions. However, 2D cadastral systems are able to cope with each type of rules. It will be necessary to achieve the same for 3D cadastres, i.e., find definitions and technical (geometrical) solutions that are general enough to fit into every legal framework without too much effort. This would then make knowledge gained by national projects transferrable to other countries.

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