Possibilities of Integrating Public Law Restrictions to 3D Cadastres

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Key words: PLR, RRR, 3D Cadastre, Legal Framework

SUMMARY

Modern urban environment is characterized by intense vertical exploitation of real property. This has resulted in complex and interlocking structures, also reflecting to vertically overlapping real property rights, intensifying the need for 3D cadastral systems. Additionally, a significant number of Public Law Restrictions (PLRs), defined by an extensive field of laws related to land, are imposed on real property, due to the need of legally implementing public benefit, thus restricting the range of individual owners' rights. This implies both their physical extent in 3D space and power to act on real property deriving from each right. During the years, it is essential that these restrictions need to be implemented, not only on land surface, but also in 3D space, in order to comply with the vertical expansion of structures. PLRs have considerable influence on Land Administration, as they directly affect land use, urban planning and management, land values, land titles' credibility and every other activity related to land exploitation. The significance of PLRs in Land Administration and management has been recognised by various countries internationally. A wide variety of PLRs is documented including, inter alia, environment and nature protection, water protection, spatial and land use planning zones, cultural heritage, public infrastructure corridors and zones, public easements/servitudes, mining rights and related restrictions. Each country records different PLRs in various registries, data types and formats, while in some countries, PLRs can be overlaid to cadastral parcel data. However, there has been no significant change to legal and cadastral framework in order to adjust to the 3D reality of PLRs. Therefore, vertically overlapping PLRs are presented in 2D while their vertical extent can only be identified by reference to their relative legal documentation. Given the extent of vertically overlapping real properties along with the wide range of PLR imposed on them, it is clear that legal and cadastral framework under different jurisdictions would be more efficient in Land Administration if provided for 3D definition and modelling of PLRs. This paper aims to identify and present Public Law regulations with their 3D features and investigate their potential integration to cadastral systems. To this aim, cases of above and/or below land surface PLRs are examined, exploiting cadastral survey data compiled within the Greek legal framework. The outcomes of this research can be used by interested parties to allow for clarification of complex, overlapping Public Law defined legal spaces, 3D visualisation and 3D modelling.

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1. INTRODUCTION

Growing accumulation of population in urban areas during the years forced for vertical exploitation of real property, both for accommodation purposes and to respond to the emerging public needs related to the amenities required by modern societies (Stoter, 2004; Kitsakis and Dimopoulou, 2014). Technological advances in recent years allows for extensive vertical land exploitation through the development of complex, overlapping and interlocking structures. Furthermore, development of surveying techniques as well as information and computer technology (ICT) provides the means for accurate data recording, modelling and management of 3D models in real time; research on 4D and 5D representations is also available in literature (v. Oosterom and Stoter, 2012; Ohori et al, 2013), taking into account aspects such as scale and time.

On the other hand, exploitation of real property is regulated by national legal framework, based on Roman principles of real property, specifically regulated to address overlapping private and public rights. Taking into account aforementioned technological abilities, the variety of Public Law Regulations (PLRs) on land can be modelled in benefit of the public, professionals and land administrators. Efficient modelling and visualising PLRs can only be achieved if operating in combination with cadastral systems in multipurpose approach, contributing to land administration, decision-making and development.

This paper presents the range of PLRs with 3D aspects, that impact on real property, along with cases of 3D PLRs justifying the need of 3D PLR recording to allow for efficient land management and decision-making. The paper is structured as follows: Section 2 classifies PLRs and presents 3D restrictions that they impose on real property, while section 3 presents efforts to record PLRs worldwide. Section 4 describes three individual cases of 3D PLRs applying in Greece. In section 5, discussion and conclusions on the examined topics are provided, while section 6 includes issues that would be of interest for further research.

2. PUBLIC LAW

Public Law has significant effect on modern societies. For example, approximately 150 laws, ordinances and regulations regulate aspects of contemporary life in Switzerland (Givord, 2012) (Fig. 1). To the field of Land Administration, Public Law's effect has grown over the years, both due to the need of regulating vertically overlapping, conflicting activities and to secure public benefit. To this aim, law obliges land owners to tolerate on their land, constructions owned by others (Ploeger and Stoter, 2004). Such effect does not directly derive from land laws, but from legislation pertaining urban planning, mineral activities, archaeology, underground water, pollution, environment, aviation, infrastructures, utilities and constructions that require multi-surface land management. Given the growing number of Public Law regulations, intense vertical exploitation of real property, lack of centralised

recording of PLRs as well as their 2D based definition, real property related development can get complicated, delayed or, in complex cases, even jeopardised.

The effect of 3D aspects of PLRs should not be underestimated. Although real property is not explicitly three-dimensionally defined, the need of its 3D segmentation is evident e.g. condominium, servitudes, rights of superficies, SRPO, 3D real property (where applicable).

Figure 1. Public Law restrictions in everyday situations. Source: Barbieri, 2015

Characteristic cases of 3D PLRs on land, resulting by literature research, are briefly presented in the following section. 3D PLRs were classified based on the different branches of Public Law. Depending on each country's legal and administrative framework regarding PLR recording, different classifications may apply.

2.1 Mines

Mineral laws and codes constitute common examples of Public Law effect on real property. The significance of minerals not only in terms of national economy, but also in terms of international relations and politics, has been early recognised, thus resulting in legislative separation of land from mineral ownership, to secure public benefit.

Currently, mineral rights are considered as real estate properties, distinct from land ownership (with some exceptions in US states) and are registered to mining cadastres. Granting mining rights does not require approval from surface parcel owners (Ortega, 2013), while in a significant number of countries mining cadastres are operating (World Bank, 2009). Mining cadastral units involve quadrangular polygons with constant dimensions that refer to and have a fixed position within a system of (2D) coordinates (World Bank, 2009). Although mineral overlapping rights are not common practice due to technical reasons, mining areas may overlap either with other PLRs (e.g. environmental protection or archaeology), infrastructures or structures located on their surface parcel(s). Exploitation of 3D PLRs for mining purposes would be of great benefit both for mining industry and national and local economies, by defining, presenting and securing overlapping rights on land. Taking into account that there is already a number of countries allowing use of mining licenses as collateral, e.g. Canada,

Chile, Peru and South Africa (World Bank, 2009), land administration would benefit from converting mineral rights to 3D Cadastre PLRs.

2.2 Archaeology

Archaeological legislation also poses significant restrictions on real estate property rights. Depending on the type of antiquities, as defined in national legislation, different restrictions or responsibilities apply to land, ranging from preserving a building part operationally or allowing extraction of antiquities found below the land, to land expropriation. International literature review provides the following measures stipulated by legislation protecting monuments or archaeological sites:

- delimitation of buffer zones and implementation of appropriate zoning and planning regulations;
- easements and other similar rights over land in the vicinity of an ancient monument, agreements concerning ancient monuments and land in their vicinity;
- expropriation of a whole land parcel or part of it;
- right of pre-emption;
- restrictions in real estate property uses concerning those that may destroy or harm the monument directly, or indirectly, mineral exploitation, and extraction, establishment of telecommunication equipment, industrial and commercial installations and constructions in the vicinity of monuments;
- restrictions in constructing new buildings, alteration, restoration and use;
- restrictions in maritime activities within or in the vicinity of marine antiquities.

Except of pre-emption rights, all of the above measures involve 3D aspects that would assist both in efficient protection of monuments and archaeological sites and land management. A characteristic example is the establishment of maximum building height in the vicinity of monuments or archaeological sites, or structuring restrictions concerning under and/or above ground constructions, e.g. establishment of protected vistas in London (Fig. 2).

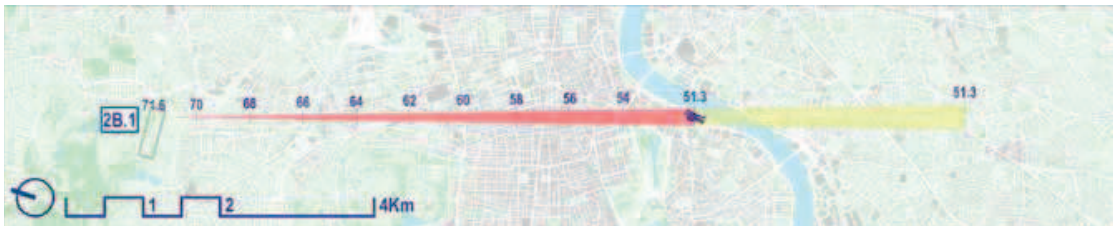

Figure 2. Protected vista to Palace of Westminster (Source: Greater London Authority, 2012)

2.3 Environment

Environmental legislation includes a variety of laws regulating waste management, pollution, marine space management and (underground) water protection. Characteristic examples can be traced in European Union legislation. Council Directive 1999/61 on the landfill of waste defines the general requirements for landfills, taking into account location factors, e.g. distances from their boundaries to residential, recreational, agricultural or urban areas, the existence of groundwater, geological and hydrogeological conditions as well as protection of nature or cultural patrimony in the area (Annex 1). Similar provisions are also provided for water control, leachate management and soil protection. As soil contamination can be

detected through measuring of substance concentration per soil volume, it is evident that PLRs related to management and remediation of contaminated soil would prove most efficient if defined in 3D. Soil data is extensively recorded by the European Soil Data Centre, so it can be used in combination with environment regulations regarding polluting factors, e.g. industrial or urban sources, leading to generation of 3D soil regulations.

Waste management is also related to groundwater protection legislation, as groundwater can be polluted by hazardous waste through leaching. EU Water directive 2000/60 Annex II requires initial characterisation of underground water bodies failing to meet Directive's objectives, and further characterisation for those that are at risk and further assessment of risk's significance is required. In both cases, geological, hydrogeological, land use and other relative data is required. Combination of groundwater course along with geological characteristics of the area can also result in definition of a 3D zone along the groundwater course, to protect it from leaching.

Management of marine space legislation also constitutes a characteristic example of 3D PLR Cadastre, although it requires to be accommodated within marine cadastral systems. Legislation provides for a variety of activities on water parcels including fishing, trade, mining and minerals exploitation, undersea cables and pipelines, fishing and aquaculture, shipping and transportation, military exercise areas, wind energy, recreation areas, nature conservation and archaeological sites, scientific research, pollution management and dumping sites (Netherlands, 2000). Each of these activities requires 3D definition of the zones where each related RRR is exercised.

A problem of defining environmental PLRs has to do with the fact that environmental regulations apply not to specific regions, except of statutory defined protected areas, but depend on each development's characteristics. In this case, characterisation of an area as able to support specific environmental restrictions would partially accommodate the problem as it can only apply to limited extent (given current technological capabilities and legal definition of PLR).

2.4 Civil aviation

2.4.1 Non-military manned air-vehicles

Aviation related PLRs do not only imply overflight rights, which are already dealt with by the International Air Services Transit Agreement 1944 (Art. I, Sec. 1). It is also related to restrictions imposed on constructions in the vicinity of airports, such as building heights or restrictions in land use. Some of the most common aviation PLRs are presented below.

- Definition of special flights' rules such as non-flight zones (to the airspace below a specific extent or to the whole airspace above a region). Such zones are defined by their latitude and longitude, along with allowed airspace flight height, if applicable.
- Definition of general minimum flight height.
- Definition of Obstacle Limitation Surfaces (OLS), designating the airspace around an airport where restrictions apply to constructions' or physical objects' heights (Fig. 3).

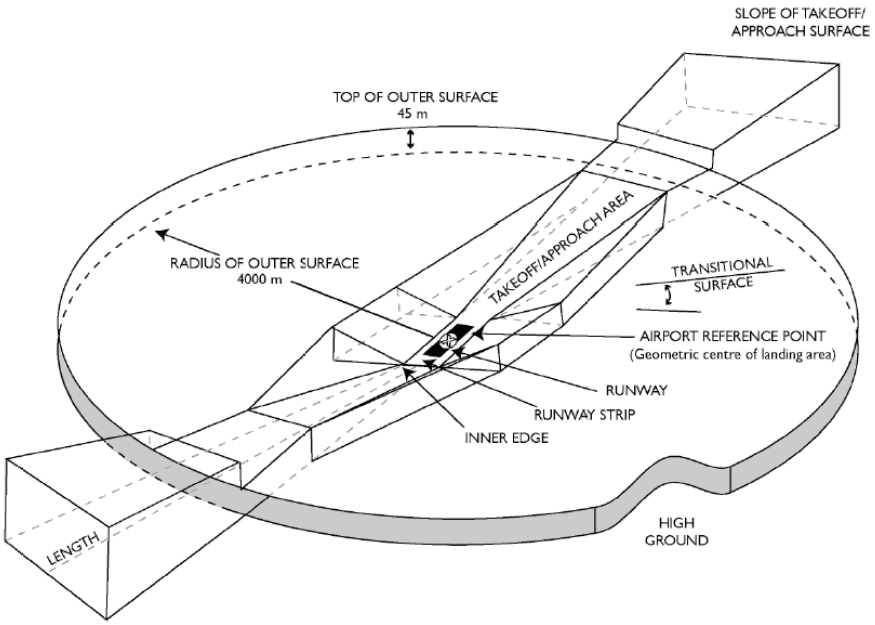

Figure 3. Obstacle Limitation Surfaces (OLS)
(Source: https://www.tc.gc.ca/eng/civilaviation/publications/tp1247-part1-1417.htm)

Such regulations are stipulated by national legislation and are based on International Civil Aviation Organisation (ICAO) standards and recommended practices. It is evident that 3D representation of aviation PLRs would benefit both civil aviation and land management allowing for more effective exploitation of land in the vicinity of airports, also ensuring safe air navigation. To this aim, research towards generation of electronic terrain and obstacle databases (eTOD) is conducted exploiting the variety of data acquisition techniques. ICAO Doc 9881 (Guidelines for Electronic Terrain, Obstacle and Aerodrome Mapping Information) defines terrain and obstacle attributes to be recorded using 3D characteristics. ICAO provides a variety of eTOD GIS prototypes as well as 3D Obstacle Identification Surfaces using various visualisation tools, as presented in Figure 4.

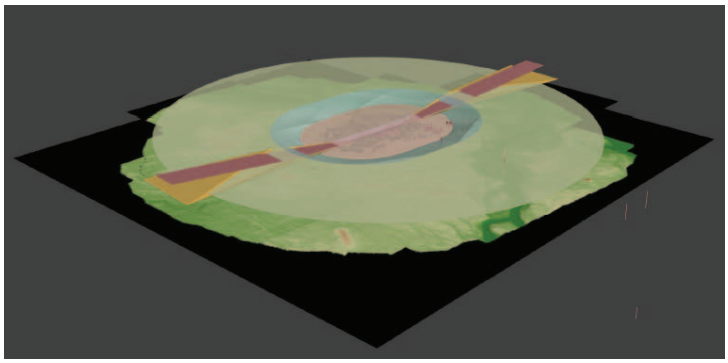

Figure 4. 3D eTOD Obstruction Identification Surfaces in 3D pdf
(Source: http://gis.icao.int/ETOD/tod.pdf)

2.4.2 Unmanned Air Vehicles (UAV)

Unmanned Aerial Vehicles (UAV) for civil purposes has grown popular over the last years. Therefore, need of regulating their use involving issues of safety, privacy, security and data

protection has emerged. Regulations addressing UAV flights share similar characteristics with aviation of manned air vehicles, however, their extended use for recreational and commercial purposes, along with their lower height levels have resulted in to need of further regulating such systems' operation. The variety of PLRs applying to UAVs cannot be totally incorporated within 3D cadastral systems, as there is a significant number of regulations applying to variable conditions such as public assemblies, hunt areas, areas where emergency operations take place, etc. Common 3D PLRs regarding UAV flights globally, include:

- Fly under permission above specific heights
- Flight prohibition over infrastructures or correctional facilities
- Definition of maximum flight height

2.5 Urban planning and construction regulations

2.5.1 Urban planning

Urban planning and construction regulations also impose 3D restrictions on real property. Billen and Zlatanova (2001), identify the impact on land ownership by geographical phenomena, along with 3D segmentation of space and 3D spatial analysis as applications of 3D modelling to 3D Cadastre; such identification points out 3D urban planning PLRs which would contribute to efficient land management through 3D PLR recording.

Urban planning derived PLRs regulate a significant number of fields including land use, major infrastructure and development, implementation of special economic policies, transport, education, energy consumption, public investments, environment and traditional architecture preservation. Implementation of such policies depends on each country's legal and administrative framework. Newman and Thornley (1996), examine the factors influencing urban planning in European cities, tracing major legal and administrative differences which are mitigated by EU initiatives towards decentralisation and regionalism.

Depending on national and regional initiatives on urban development, different urban planning regulations apply, which impact on society, environment and other policies, e.g. pollution, carbon emission, land use change, effects on environment caused by energy production and consumption (Singh et al, 2015). The "Guidelines for new development in the proximity to railway operations" in Canada, stipulate mitigation measures for new structures in the proximity of railway corridors (Figure 5) regulating safety, noise, vibration and trespass issues.

Similar regulations are also stipulated to New South Wales "Development Near Rail Corridors and Busy Roads – Interim Guideline" (2008). The same guide provides for vibration and excavation measures in the proximity of rail corridors and roads to prevent structures' subsidence and deterioration as well as to ensure soil stability.
Immissions include air pollution, noise, vibration, light, heat, radiation and similar effects on the environment affecting humans, animals, plants, soil, water, atmosphere, cultural objects and material goods (German Federal Immission Control Act, 2002 according UNEP, 2016). Each of the above mentioned immissions includes 3D aspects although at different level, which can be used to define immissions falling into 3D PLR Cadastre.

EU Directive 2002/49 already provides for compilation of noise maps and strategic noise maps (Art. 4) while Annex I defining noise indicators stipulates specific heights for noise indication measurements. Given its 3D propagation, noise regulations can be more efficiently managed through 3D representation (Givord, 2012). 3D data such as building heights, noise barriers and topography are taken into account for noise calculation; however, in most cases 2D noise maps are compiled, that do not allow insight to the 3D aspects of noise (Stoter et al, 2008). To this aim, research towards generation of 3D noise maps is conducted, including 3D noise maps of Paris (Butler, 2004), Delft (Stoter et al, 2008) and Hong Kong (Wing and Kwong, 2006). CityGML Noise Application Domain Extension (ADE) has been developed to allow for 3D noise mapping along with exploitation of topological and semantic features provided by CityGML, e.g. application for noise mapping in North Rheine-Westphalia (Czerwinski et al, 2007). Public Law also regulates issues related to radio waves propagation to ensure efficient communication and broadcasting as well as protect public health and natural environment from extended exposure to electromagnetic fields. Public exposure to electric and magnetic fields and installation of antennas (for radio communication and broadcasting) are regulated through imposing restrictions to their distance from specific sites, frequency range and antenna tower heights.

Regulations on buildings' height for visibility purposes also constitute an urban planning derived PLR. There are various restrictions applying within urban landscape in order to protect landmarks and their visibility, e.g. London View Management Framework (Greater London Authority, 2012).

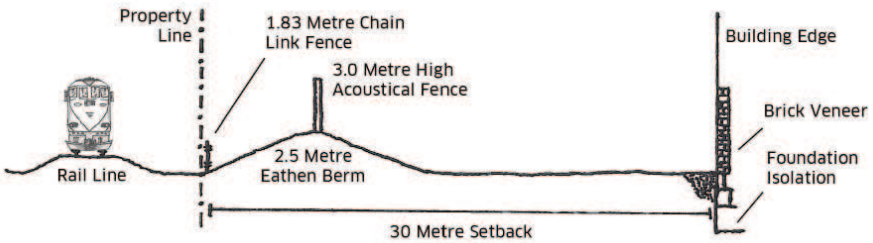

Figure 5. Mitigation measures for developments in the proximity of railway (Source: Guidelines for New Development in Proximity to Railway Operations, 2013)

2.5.2 Construction regulations

3D PLR also include construction regulations. Specifically, construction regulations stipulate allowed building height, depending on land parcel's location and area, as well as building's intended use, thus defining permitted building volume. Given the need of reducing energy consumption, building codes also define regulations regarding buildings' lighting, ventilation and solar exposure which pertain 3D aspects and are influenced by surrounding buildings and constructions on 3D space, e.g. shadow casting of a building to neighbouring buildings. Such regulations combined with energy requirements of already built constructions can also be used to export building energy demands in urban areas which can be further exploited within urban planning regulations.

Additionally, where urban landscape requires being protected, specific building regulations apply to protect traditional architectural characteristics of buildings, e.g. facades or interior design.

2.6 Utilities

Serving the needs of growing urban population requires establishment of extended utility networks. Such networks are established in both private and municipal land, on which PLRs are imposed to promote public benefit. Utilities comprise not only structures, such as underground parking stations, tunnels, pipelines and telecommunication networks but also intangible assets such as radio waves. Public Law imposes restrictions on real property to facilitate networks' establishment and use, in case of constructions supporting utilities.

In most cases, installation of utilities require establishment of utility servitudes (Kitsakis and Dimopoulou, 2014), while specific laws may impose restrictions on surface parcels regarding a utility. For example, Law 1955/1991 (Art. 10) in Greece for the establishment of Athens subway, allows Athens subway tunnel excavation to required depth without compensation to surface parcel owners if land parcel's normal use is not affected. In case of pipelines or power lines, building and agriculture restrictions apply to specific distance from pipeline's or power line's centre-line. Such restrictions involve allowed building depth and height, cultivation restrictions as well as establishment of utility servitudes to allow access and maintenance of the utility, also providing for compensation of the surface parcel owner.

3. RECORDING OF PLRS

3.1 Themed cadastres

During the years each country has developed various registries recording real property data (Kitsakis and Dimopoulou, 2014) also including PLRs. In Europe, twenty two countries record PLRs ranging from environmental to noise and mining restrictions (Steudler, 2015). Each country, depending on its legal and administrative framework and spatial infrastructure may provide for overlay of PLR to cadastral parcels.

According to authors' literature research, PLR recording mostly involves environment related regulations such as environment and nature protection, (underground) water protection, polluted and contaminated sites, as well as archaeological PLRs, a trend also applying in a significant number of European countries (Barbieri, 2015).

PLRs may be recorded to Cadastre, e.g. Tte Netherlands, in separate registries (themed cadastres), e.g. Archaeological Cadastre in Greece, or both, e.g. Denmark. Themed cadastres which focus on specific objects' recording are usually established to record PLRs. However, this only constitutes partial PLR recording while it emphasises more on recorded objects than on the restrictions imposed on real property. Some of the most common types of themed cadastres that are established are utility cadastres, archaeological cadastres and databases recording contaminated sites and protected areas. Queensland's Environmental Offsets Regulation, stipulates that an administering agency must keep a registry recording, inter alia, "particulars sufficient to identify the area". Similarly, EU Directive 2000/60 provides for

"register of all areas lying within each river basin district which have been designated as requiring special protection under specific Community legislation for the protection of their surface water and groundwater or for the conservation of habitats and species directly depending on water."

In Latvia, Restricted Territories Information System (RTIS) has been established to inform public about restricted territories and protection zones (Rudzītis, 2015). RTIS records a variety of restricted zones including environment and nature protection, exploitation protection, sanitary protection etc. Underground utility lines and structures are presented on Latvian State Land Service Portal in 2D cadastral map, using specific symbology. In Slovenia, an extended Public Utility Infrastructure Cadastre has been established since 2004 (Petek, 2015) recording roads, railroads, electricity, gas, heating water, sewage and telecommunications. Apart from Utility Cadastre, Slovenian Spatial information System also includes Land Cadastre, Building Cadastre and Land Use database, which operate as a Public Law Restrictions record (Petek, 2015).

Restrictions on real property deriving from archaeological findings are recorded to Archaeological cadastres. Although archaeological cadastres do not constitute complete PLR records, they can prove useful in assisting land administration through providing regulations that apply to archaeological sites and their vicinity. Each country implements its unique cultural heritage recording system. The Netherlands register restrictions imposed by the Law on Monuments on the whole parcel, while indication that such a restriction affects part of a land parcel can be added to the administrative part of the registration (Stoter and v. Oosterom, 2006). Registration of monuments to the cadastre is not very common, as separate archaeological GIS have been established, exploiting however, cadastral basemaps. Other examples of archaeological cadastres are the Archaeological Cadastre of Slovenia (ARKAS), the Danish National Record of Cultural History (DKC) or the Hellenic Archaeological Cadastre. Such registries use 2D maps and coordinates while make no reference to vertical restrictions on real property above or below land surface. Legal restrictions applying can be recorded, depending on each country's administrative framework, to be used by the involved agencies.

3.2 PLR Cadastres

3.2.1 Swiss PLR Cadastre

Swiss PLR Cadastre is an initiative started in 2014 and expected to be completed by 2020 (Federal Office of Topography swisstopo, 2015). Currently, eight Swiss cantons have established pilot PLR cadastres.

Due to Switzerland's administrative system, PLR Cadastres record 10 PLRs at federal level and 7 imposed by cantonal law (Givord, 2012). Act on Geoinformation provides that additional PLRs may be defined by the cantons to be recorded to the PLR cadastre (Art. 16, par. 3). Currently, according to the Federal Office of Topography (2015) Swiss PLR cadastres record 17 restrictions classified in 8 sectors as presented in table 1:

Table 1. PLRs recorded to Swiss PLR cadastres

Sector	Restrictions
Contaminated sites	Cadastre of contamined sites Cadastre of contamined military sites Cadastre of contamined sites at civil airfields Cadastre of public transport contamined sites
Railways	Project planning zones for railways Building lines for railways
Airports	Project planning zones for airports Building lines for airports Security zone plan
Groundwater protection	Groundwater protection zones Groundwater protection area
Noise	Noise sensitivity levels (in land-use zones)
Motorways	Project planning zones for motorways Building lines for motorways
Spatial Planning	Land-use planning (cantonal/municipal)
Forests	Forest perimeters (in building zones) Forest distance lines

Above mentioned PLRs are presented as 2D polygons on 2D maps, although pertaining 3D characteristics, e.g. contaminated sites, airports, groundwater protection, noise and spatial planning, implied in relevant legislation but not accurately defined. For example, groundwater protection could restrict establishment of pipelines or underground utility networks within a specified vertical extent in subsoil. Similarly, high concentration values of pollutants may require vertical restrictions to be imposed below land surface to prevent contamination of groundwater. Restrictions on allowed building heights are also provided by PLR cadastres, but only as defined to the legal documents that accompany PLR cadastre extract, imposing each restriction e.g. maximum building heights imposed by construction laws.

Givord (2012) highlights the interest of the canton of Geneva to establish 3D PLR Cadastre. Initiative "Charte d'ethique de la 3D" in 2010 to secure credibility and transparency of 3D data also justifies inclination towards 3D land management. In his study, he has developed a prototype to present and manage PLRs in 3D, while concludes that current 2D based legislation, implying 3D aspects, along with complexities in performing spatial analysis in 3D hinder transition to 3D PLR cadastres.

3.2.2 Restrictions Information System (RIS) in Estonia

According to Article 12 of Land Cadastre Act of Estonia "The cadastral registrar shall enter the location (boundaries) of objects which give rise to restrictions on the use of a cadastral unit on the restrictions map and, if necessary, shall specify the scope of such restrictions". To this aim, Republic of Estonia has introduced an integrated to the cadastral system, restrictions registration system recording descriptive and spatial characteristics of PLRs (Land Board of Estonia website).

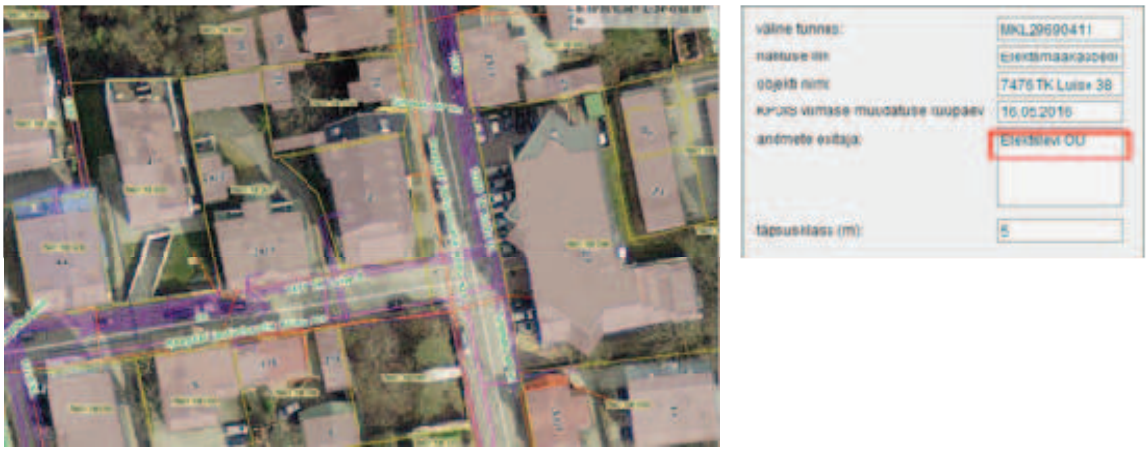

Figure 6. Underground powerline as presented to Estonian RIS. (Source: Restrictions Application portal)

This system is under development since 2002. It comprises of a significant number of PLRs such as environmental, water protection, utility networks and state facilities (Kuus, 2011). Although objects recorded as giving rise to Public Law restrictions are regarded those that can be spatially defined using X,Y,Z coordinates, Restrictions application of Estonian Land Board Geoportal does not include 3D PLR zones, nor does it present restrictions that extend vertically. Figure 6 presents an underground electricity line on the Estonian RIS.

4. 3D PLR CASES FROM GREEK PUBLIC LAW

This section presents 3 characteristic examples of PLRs applying in Greece. Greece is currently under cadastral survey to complete its cadastre. Cadastral law does not provide for the recording of PLRs during this stage of the project; however it stipulates that the Hellenic Cadastre will be open for other types of data that may require being recorded in the future (Law 2664/1998, Art. 2). As there is a significant number of PLRs implying 3D aspects, which however are not recorded to the Hellenic Cadastre, this section examines PLRs imposed by Aviation Law, Construction Law, and specific laws applying on the establishment of public utilities.

4.1 Establishment of no-flight zone in the proximity of Archaeological antiquities

In this case, the establishment of a no-flight zone around Acropolis in Athens is presented. Presidential Decree 24/2007 defines a circular no-flight zone to protect archaeological monuments. The centre of the cycle is defined using East/North coordinates (Fig. 7 left) along with its radius, while two separate flight height restrictions are imposed for propeller aircrafts (starting from ground level to 5000 feet) and Jet aircrafts (starting from ground level to 10000 feet). Figure 7 (right), presents such non flight zones overlaid to Hellenic Cadastre's orthophotos. Flight zones are not recorded to the Hellenic Cadastre, while there is no provision for registration of such restrictions to Hellenic Cadastre descriptive database. Combination of these restrictions with PLRs deriving from building legislation on the relative area, as well as public utilities' and Unmanned Aircraft Systems' (UAS as defined in relative Greek regulation which is not yet put to vote on the Hellenic Parliament) restrictions would

provide exploitable 3D space, thus contributing to efficient land management and development of real estate market within each region.

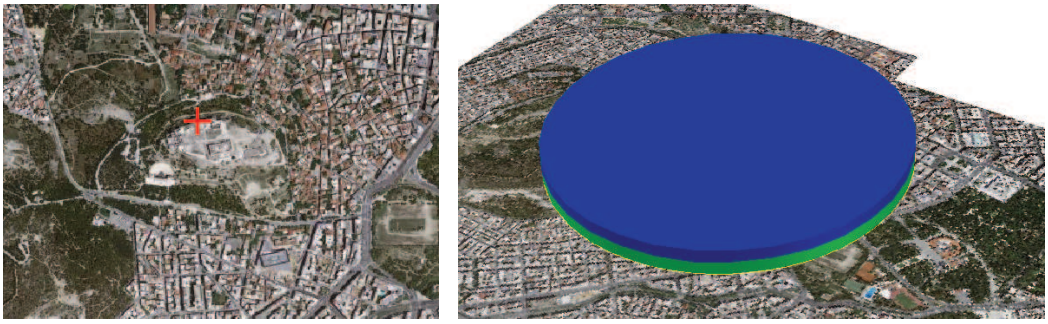

Figure 7. (left) Centre of no-flight zone in NCMA orthophoto (red cross), (right) No-flight 3D volumes in Autodesk AutoCAD software (no flight zone for propeller aircrafts is coloured in green while no flight zone for jets in blue)

4.2 Construction Law

In this subsection, Construction Law derived PLRs are examined, applying to the industrial area of Tripoli in Greece. Building restrictions that apply to the industrial area of Tripoli are defined by Presidential Decree (Official Gazette D' 632/9.10.1989). Industrial area is divided in three zones, depending on intended use (Fig. 8 left- Gatsogianni, 2016).

For each zone, specific building restrictions apply regulating built-surface ratio, minimum land parcel size, site coverage ratio and maximum building height, while utility establishment is regulated by legislation related to each utility. Building restrictions are available descriptively at the aforementioned legal document. Spatial data includes area delimitation and land parcel boundaries presented as 2D polygons. Implementation of vertical building restrictions on 2D polygons, provides permissible building volumes (legal spaces) as presented on Figure 8, right.

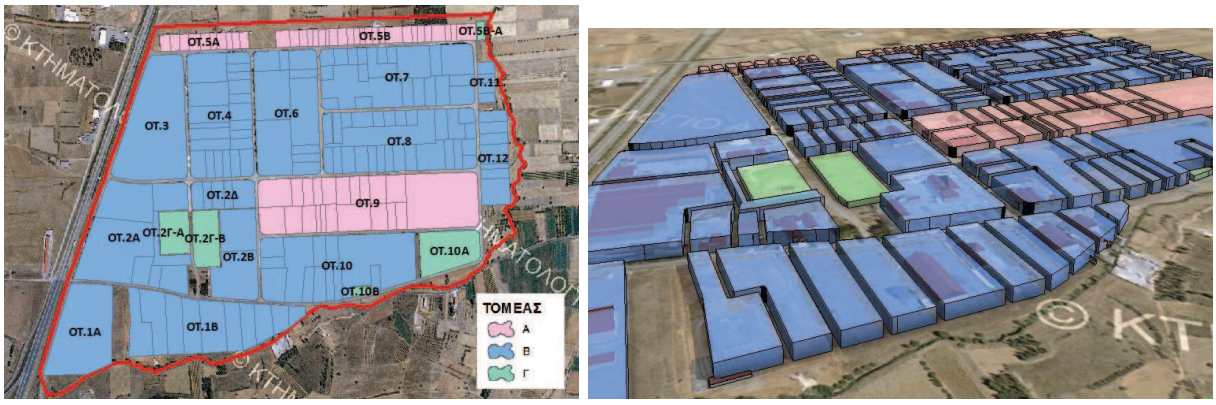

Figure 8. (left) Building restrictions in Tripoli industrial area, (right) Implementation of building restrictions to generate legal spaces (Source: Gatsogianni, 2016)

4.3 Public utilities

This subsection presents 3D PLRs applying for the establishment of public utilities, specifically a power line lying above ground, outside urban planning zone in the region of Attiki in Greece.

Restrictions on real property for the establishment of public utilities in Greece are imposed by specific laws, decisions or decrees. In the examined case, relative Ministerial Order provides for the expropriation of $16m^2$ or $4m^2$, depending on each parcel, for the installation of electricity power lines and the establishment of servitude of passage extending 6,25 m along the power line centre line. Within servitude of passage zone, entrance is allowed for inspection, repairing and maintenance of the power lines by Public Power Corporation personnel, while it is not allowed to build any other construction or installation more than 5 m high. Figure 9 presents part of the cadastral survey plan of the area, while the plan incorporating 3D restrictions applying is presented in Figure 10.

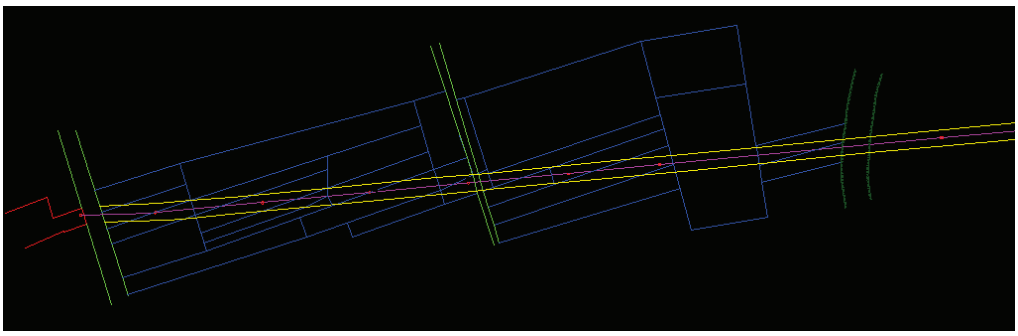

Figure 9. Cadastral survey plan of power line (down) presentation of 3D restrictions due to servitude of passage (servitude is coloured in yellow, powerline centre line in purple, land parcel borders in blue and roads in green)

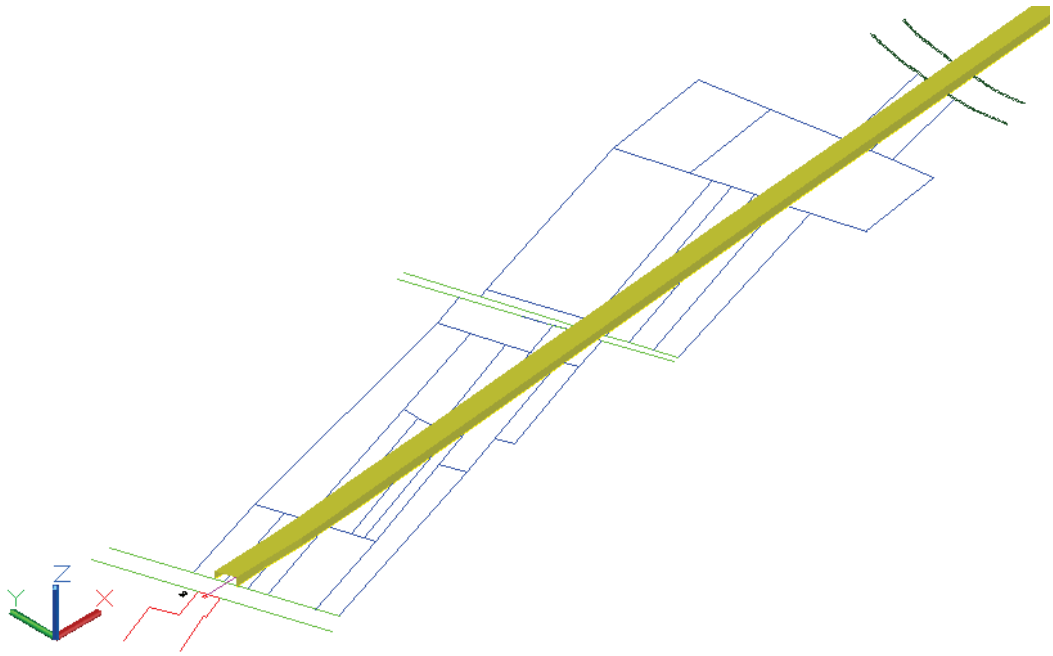

Figure 10. Presentation of 3D restrictions due to servitude of passage (servitude is coloured in yellow, powerline centre line in purple, land parcel borders in blue and roads in green)

4.4 Results

Preceding subsections presented a selection of PLRs that involve 3D aspects within Greek Public Law. Each case examined shows that Greek Public Law provides for 3D restrictions on real property to secure public benefit. However, such restrictions are only descriptively defined in specific legal documents hindering easy access and distinct presentation of 3D restrictions' extent on 3D maps. It needs to be noted that neither no-flight zones are recorded, even descriptively, to the Hellenic Cadastre, nor building restrictions. Only projections of utility servitudes' zones are presented on Hellenic Cadastre maps. Cadastral Law 2664/1998, does not provide for Public Law restrictions to be registered to the Hellenic Cadastre. Yet principle of the "open Cadastre" allows for further enrichment of cadastral databases with additional information in the future (Art. 2). In case where restrictions on real property are recorded, e.g. servitudes of passage for utilities passing through private real property, servitudes' type and extent on land parcels are presented, while further restrictions implied by the servitude are neither recorded nor presented to the cadastral maps.

3D representation of building restrictions provides clarity in defining the legal volumes within which each construction shall be built. However, complexities may arise due to different implementations of building restrictions, e.g. a building may have multiple basements if their total area does not exceed site coverage ratio area as defined in Greek building regulation (Mpoutou-Lempesi, 2013).

5. DISCUSSION AND CONCLUSIONS

From the above, it is evident that 3D PLRs influence land administration to a significant level, while such influence is growing due to the increasing number of restrictions in land and the space above and below it. Public Law either imposes 3D restrictions on real property, or stipulates restrictions on the land surface applying to the space above and/or below. In both cases such restrictions can only partially address the problem, as 3D restrictions are not operating within a 3D cadastral context and are available only in legal documents or 2D maps so cannot be fully effective, while 2D restrictions extending in 3D result in ambiguities in presentation (if provided) and interrelation with other 3D restrictions. Table 2 below, summarises PLRs traced in literature research and their actual mapping, where applicable.

Currently, there are several databases internationally recording PLRs either as themed cadastres recording specific objects, which are the most common, or by establishing PLR cadastres, such as the Swiss PLR Cadastre or Esthonian Restrictions Information System. However, both themed cadastres and PLR Cadastres address them in 2D using 2D representations even in case of 3D restrictions. PLR recording definitely promotes efficient Land Administration, although 2D nature of such data is possible to result in similar issues faced already by real property cadastres.

Definition of PLRs' extent in 3D space is a difficult task as they are influenced by various factors which are not always easy to be mapped, while require constant updating. For example, environmental PLRs require a wide variety of data such as geological data,

concentration of pollutants in soil, air or water etc., to be combined in order to generate a restriction in 3D space which changes over time.

Table 2. Types of 3D PLRs and their mapping in relative records

Legislation	Types of restrictions	Mapping (2D/3D)
Mines	• Separation of land and mineral ownership	2D
Archaeology	• Establishment of protection buffer zones • Parcel (or parcel's part) expropriation • Establishment of servitudes • Land use restrictions	2D (restrictions in height may also be defined)
Environment	• Distances from agricultural, rural etc areas • Existence of groundwater • Geological and hydrogeological conditions	2D
Aviation	• Establishment of no-flight zones • Minimum flight height • Definition of Obstacle Limitation Surfaces	2D/3D
Urban Planning	• Noise maps • Protection of landmarks' view • Limitations in height, built-surface ratio, shadow casting	2D (restrictions in height may also be defined) 3D noise maps
Utilities	• Restrictions along centre-line	2D

Definition of PLRs in 3D space along with relative 3D modelling would constitute an efficient tool to clarify complex cases of vertically overlapping restrictions, present the exact space where a restriction applies, encumber specific 3D spaces instead of a whole land parcel and facilitate efficient 3D space exploitation and operation of the land market.

Introduction of 3D PLRs will in many cases involve conflicts in 3D space, e.g. utility establishment where archaeological or underground water protection restrictions apply. Such conflicts justify the need of establishing PLR Cadastres due to interrelation of multiple, conflicting restrictions in 3D space. According to the authors, there should be no distinction between 3D Cadastre PLRs and PLRs recorded to specific registries. It is vital to avoid ambiguities deriving from a "dual" system of PLRs by establishing a single PLR record. The example of Swiss PLR Cadastre, although not in 3D, provides a characteristic case of the benefits of a single PLR database. Resolution of conflicts between 3D PLRs should not be addressed differently from already in force PLRs, i.e. through provisions in relative laws or by bringing them to court.

6. FURTHER RESEARCH

Establishment of 3D PLR Cadastres involves a broad range of issues that require further research.

One of the first steps that the authors consider to be required is definition of PLRs that described in 3D would contribute to more efficient land management, along with stipulation of their volume. This involves legislative amendments to redefine relative PLRs in 3D and convert multiple factors' impact in 3D space, e.g. in case of establishment of underground

water protection zones. Representation of PLRs in 3D introduces further issues on securing 3D data accuracy and regular updating. Introduction of "Charte d' éthique de la 3D" already numbering 314 members (Charte d' éthique de la 3D website), highlights such need.

Given that implementation of operating 3D PLR Cadastre requires 3D partition of space, introducing 3D Cadastre legislation would contribute to a fully operational 3D PLR Cadastre. Towards this direction, arbitration processes require to be developed, to address 3D conflicts between complex, 3D overlapping PLRs along with their interrelation with private rights. Priorities need to be set to balance between personal interests and societal needs (Navratil, 2012). The nature of PLRs in national legislation also impacts on the content of ownership right, as, depending on national legal systems, they can be regarded as external restrictions on (unlimited) total, immediate and absolute power deriving from real property ownership, as inherent restrictions to the nature of ownership, or as restrictions that apply on exercising power deriving from ownership right (Georgiadis, 2012). Such distinction, which requires legal experts' contribution, would allow for apprehending the nature of ownership and of restrictions imposed on it, thus facilitating land management both for the public and professionals.

In this paper the authors aimed to introduce the need of defining and presenting PLRs in 3D, by presenting restrictions imposed on real property by Public Law and their impact, while presenting 3 individual cases of 3D PLRs in Greece. The next stage of this research involves full examination of a case study including every PLRs applying, as well as their interrelations and impact on land development and management.

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