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Review

Public Law Restrictions in the Context of 3D Land Administration—Review on Legal and Technical Approaches

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Abstract: Intense exploitation of land implies the development of multi-level, multi-purpose, overlapping and interlocking structures on 3D space, thus resulting in complex, stratified, 3D real property rights between individual owners, as well as restrictions. Legislation regulates the ownership status and use of land by imposing restrictions known as Public Law Restrictions (PLRs). PLRs extend to various fields and various legislative frameworks, such as the protection of archaeological sites, protection and maintenance of underground infrastructures and utilities, environmental protection, flying of unmanned air vehicles, etc. PLRs are usually investigated in the context of property rights and restrictions in the various Land Administration Systems worldwide, and do not often gain specific attention. However, it is noticed that the restrictions that arise from Public Law need to be investigated and classified, so that they can be better utilised in the property status of land ownership. This review paper investigates the legal statutes on PLRs within the context of 3D land administration and the stipulations used to provide unambiguous modelling of PLRs, as provided by the relative literature. Moreover, the PLRs applied in the 3D space, to clearly depict rights, restrictions and responsibilities on the relevant spatial unit (land, air, marine parcel, mine, utility network, etc.), are particularly examined. Therefore, this work is to critically review and assess the aforementioned approaches on PLRs' registration, modelling and organisation, as provided by a literature survey, and provides an overall view of the requirements and challenges within the development of 3D Land Administration Systems also considering standardisation developments.

Keywords: 3D cadastre; public law restrictions; 3D land administration; RRRs; standardisation

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Citation: Kitsakis, D.; Kalogianni, E.; Dimopoulou, E. Public Law Restrictions in the Context of 3D Land Administration—Review on Legal and Technical Approaches. *Land* **2022**, *11*, 88. https://doi.org/10.3390/land11010088

Academic Editor: Rohan Bennett

Received: 7 December 2021
Accepted: 4 January 2022
Published: 6 January 2022

1. Introduction

Nowadays, the built environment is characterised by interlocking structures, which result in complex overlapping Rights, Restrictions and Responsibilities (RRRs) being imposed on land/air/marine parcels. As urbanisation rapidly increases, the need for land, including both above and below ground developments, grows, while, at the same time, numerous restrictions are being imposed, reducing the availability for exploitation of 3D space. The extent and the content of the right of ownership in the various legal systems is significantly affected by legal provisions and restrictions deriving from public law (Public Law Restrictions (PLRs)). Public law comprises the rules that compel citizens to conform to the regulations of the state at the different administration levels, in the course of the exercise of state's supreme authority, or of another public law legal person [1], while at the same time pertains to relationships between individuals that are of direct concern to the state [2].

PLRs are related to the nature and content of the right of ownership, distinguishing three different approaches, as presented by [3]. The first one regards PLRs as external restrictions on the (unlimited) total, immediate and absolute power deriving from real property ownership. The second approach regards PLRs as inherent to the right of ownership and determining its content, while according to the third approach, PLRs are restrictions restraining specific powers that can be exercised from the right of ownership. The various types of restrictions on land use that arise from Public Law involve a large number of legislation systems, such as administrative regulations, urban planning, environmental protection, aerial/subsurface space exploitation, as well as water/coast protection and protected sites, while many of which are based on three-dimensional characteristics and apply to 3D space [4].

PLRs arising from the increased exploitation of space with vertical constructions and underground infrastructure have been researched by a wide spectrum of researchers worldwide and have been extensively investigated in the literature. At the international level, there are several databases recording PLRs either as themed cadastres and integrated spatial data registries, or in the form of PLR cadastres. In this scene, Switzerland realised this need early on and is one of the first countries in the world to develop a cadastre in which Public Law restrictions on land ownership are systematically documented and centrally published, in the cantonal Swiss PLR cadastres and the Restrictions Information System in Estonia. Some countries have incorporated PLRs in their Land Administration System (LAS), such as Denmark, the Netherlands and Finland [5].

The rest of the paper is structured as follows: In the "Research Methodology" subsection, the research questions that this work aims to respond are presented, along with the methodology followed. Section 2 presents an overview of the PLRs, their classification and analysis of each category, as well as a synopsis of the standardisation approaches that have considered/included PLRs. Then, the criteria for inclusion of the related studies in this review paper are considered and presented in Section 3 in the methodological steps, while Section 4 brings out the main conclusions drawn from this research, the responses to the research questions defined in Section 1 and the trends for the future.

Research Methodology

The goal of this paper is to present the literature review and organise its findings regarding the Public Law restriction investigation, modelling and organisation in an international context. Different approaches developed by various countries are examined concerning the critical management of space and the explicit representation of the RRRs that are attached to each parcel for efficient land management, thus classifying them for the purpose of this review.

To this aim, the following research questions have been defined, deriving from the legal and the technical perspective, respectively, to direct the literature research:

- Which are the legal statutes that impose PLRs within the context of 3D land administration? This question can be further specialised into the following subquestion:
    - Based on which 3D characteristics do the legal statutes impose PLRs?
- Which technical aspects regarding the modelling of PLRs are available? This question can be further specialised into the following subquestions:
    - Which standardisation options are available for registering PLRs?
    - How can the PLRs be classified in order to be modelled in 3D?

The inclusion criteria developed in the process of this review paper guide the literature search, allowing the identification of publications that meet most/all criteria. These publications are then critically analysed and evaluated. Literature research covered publications in the English and French languages, based on the familiarity of the authors. These include the following:

- Whether PLRs are organized autonomously or are integrated within national LASs;
- the time the studies were conducted;
- the classification of the PLRs in various categories;
- the issue of the third dimension in PLRs;
- the law family from which they arise;
- the technological tools used for their exploitation, organisation and visualisation.

Although this work does not claim to be an exhaustive literature review, it analyses journal publications related to PLRs, books and conference proceedings, as well as studies presented in scientific congresses and by leading organisations (e.g. International Federation of Surveyors (FIG) and EuroGeographics), representing an essential part of the research, along with the relevant legislative background. Characteristic publications referring to PLRs with three-dimensional aspects, that were used to identify the trends in their classification, registration and management internationally and within NSDIs can be traced in Section 3.

2. Categorisation of PLRs

This section focuses on the research that has been conducted in classifying, modelling and integrating PLRs into national Land Administration Systems. It is further subdivided into four subsections, investigating the types and the categories of PLRs, the technologies that are used to render PLRs in the 3D space, issues of PLRs standardisation within LASs, as well as technical implementations of countries and jurisdictions that have integrated or plan to integrate PLRs into their LAS.

2.1. PLRs' Classification

Internationally, legal systems regard the right of ownership as a social function that pertains rights, restrictions and responsibilities of its holder [6,7]. Therefore, the extent and the content of the right of ownership is significantly affected by regulations and restrictions deriving from Public Law (Public Law Restrictions (PLRs)). Public Law comprises the rules that regulate the relations between citizens and the state, compelling the former to conform to the regulations of the latter, in the course of exercising supreme authority of the state, or of another Public Law legal person [1]. Relationships between individuals that are of direct concern to the state also fall into the field of Public Law [2]. PLRs aim to promote the expansion of the national economy allowing a degree of state interventionism, to serve the purposes of social policy and to protect public benefit and national security [3]. According to [8], Public Law is the law that pertains to government, for example, constitutional separation of powers or administrative procedure; or to the vertical relation between the government and individuals to the extent that government imposes an obligation owed to it on individuals—for example, criminal law; or directly confers a right or entitlement on the latter—for example, laws pertaining to government dispensation of welfare assistance to the poor; or guarantees such individual right or entitlement—for example, constitutional law both as commanding government self-restraint and as requiring positive government intervention necessary for purposes of upholding individual rights. Considering the abovementioned components of public law, it is clear that PLRs cover an extensively wide range of fields which include a significant number of regulations, even in the case that selection is limited to land-related regulations. Indicatively, [9], identified more than 150 PLRs applying in Switzerland, while Twaroch (1998) (according to [10]) counts more than 40 laws that directly influence the use of land in Austria. Similarly [11], distinguished 620 statutes creating interests over land in the state of Victoria in Australia.

On the occasion of its workshop in 2015, the Cadastre and Land Registry Knowledge Exchange Network (CLRKEN) conducted a survey among its country members on the documentation of PLRs, and identified the most common categories of PLRs [5], as presented below:

- Environment and nature protection;
- water protection;
- spatial and land use planning zones;
- cultural heritage;
- public infrastructure corridors and zones;
- traffic lines and zones;
- forest management and protection;
- contamination sites, pollution;

- public easements/servitudes;
- coastal protection zones;
- national border restrictions;
- sea and water public domain;
- biological diversity;
- security zones;
- noise;
- concessions;
- cultivation restrictions;
- mining-related restrictions.

To efficiently organise the different types of PLRs, it is important to observe the aspects that are involved in their categorisation. With regard to their spatial connotation, PLRs can be distinguished as those that can be defined without using height or other volumetric characteristics (e.g., delimitation of urban or spatial planning zones) and others that need to be defined using 3D characteristics (e.g., construction regulations). The latter can be further subdivided into PLRs explicitly defined in 3D and PLRs whose three-dimensional character derives from non-geometrical (for example, the impact of soil's physical or hydrogeological characteristics on groundwater protection) or implied characteristics (such as aesthetic factors regarding landscape protection).

From the legal perspective, PLRs can be classified according to the branch of Public Law they pertain to, such as constitutional or administrative law. Alternatively, PLRs can be classified based on their purpose; for instance, restrictions serving national security, public health, urban planning, social and public policy, environment protection, etc.

A variation of the previously mentioned classification can be based on thematic fields of PLRs, such as cultural heritage, or urban planning legislation. Each class of this type of classification includes restrictions of both primary and subordinate legislation related to each thematic field, while more than one set of laws, regulations, ordinances or decrees may be included within a single field. For example, within the collective term of water protection legislation, statutes related to surface waters and groundwater bodies are included. This option circumvents exhaustive inclusion of the abundance of land-related PLRs that would result in highly complex and non-functional (in terms of technical capacity and cost-effectiveness requirements) structures. Based on this type of classification, [12] identified six categories of 3D PLRs, as shown in Table 1.

Selected PLRs are defined by "explicit 3D characteristics", defined by reference to height, depth and volume, compared to those characterised as "non-geometrical" PLRs that are described by reference to physical or other, non-geometrical aspects. However, as shown on Table 1, there are several of PLRs defined by statute both through explicit and non-geometrical characteristics. This reflects the fact that specific "non-geometrical" PLR subcategories need to be "translated" to height, depth or volumes, so that a complete 3D model of each PLR category can be developed.

2.1.1. Mining Restrictions

Mineral ownership is among the first cases that have arisen, requiring real property stratification. Mining concessions dating back to the 4th century B.C. can be traced in Greece [13], as well as in ancient Egypt, China, Babylon and India [14]. Management of mineral ownership, exploration and extraction rights is regulated by specific legislation, introducing a primary case of a 3D cadastral concept. The significance of minerals not only in terms of national economy, but also in terms of international relations and politics, has been recognised for many centuries, thus resulting in legislative separation of land from mineral ownership, to secure public benefit in many countries [4]. Exceptions may still be identified, for example, the no-nation state zones of high seas, where allocation and exploitation of resources are vested to the International Seabed Authority (ISA) [15], or the region of Antarctica that is governed by treaty, based on the Antarctic Treaty System [16].

Table 1. Thematic classification of 3D PLRs [12].

PLR Category	Subcategories	Explicit 3D Characteristics	Non-Geometrical	Type *
Mining restrictions	i. State-owned, landowner minerals	✓	✓	Ql
	ii. Oil, gas	✓		Qt
	iii. Terrestrial or located underwater	✓		Qt
Cultural heritage (terrestrial or underwater) restrictions	i. Archaeological sites	✓	✓	B
	ii. Monuments	✓	✓	B
	iii. Intangible cultural heritage	✓	✓	B
Environmental restrictions	i. Physical environment (geology, soils, land, hydrology, surface and ground water resources, air and noise, landscape and visual amenity)	✓	✓	B
	ii. Biological environment (aquatic and terrestrial habitats, flora and fauna, biodiversity and protected areas)	✓	✓	Qt
	iii. Socioeconomic environment (land use, demography, employment, education, infrastructure, public services and public health)	✓	✓	B
Civil aviation restrictions	i. Non-military manned air vehicles	✓		Qt
	ii. Unmanned air vehicles (UAVs)	✓		Qt
Urban planning and construction regulations	i. Urban planning	✓		Qt
	ii. Construction regulations	✓		Qt
Utilities (subsurface or aerial)	i. Development and maintenance of public utility networks and other major infrastructures (pipelines, subway lines, tunnels)	✓		Qt

* Ql: Qualitative 3D characteristics, Qt: Quantitative 3D characteristics, B: Both qualitative and quantitative 3D characteristics.

In Western countries, including both Civil and Common Law jurisdictions, legislation for mineral rights is mainly based on the following systems [17]:

- Landownership system, where the right to use and exploit minerals follows land parcel ownership.
- Concession system, where minerals are owned by the state and rights of use and exploitation are granted or conferred to interested parties.
- Claim system, where the discoverer of mineral deposits may acquire an exclusive mineral exploitation right.

Regardless of the abovementioned systems, each jurisdiction imposes nation-based regulations, reflecting each country's specific legal and cultural background, its economic policies, environment protection and land administration priorities. For example, according to South African legislation prior to 2002, mineral ownership was based on surface parcel ownership and could be privately owned [17]. However, the Mineral and Petroleum Resources Development Act of 2002 incorporates social aspects into mineral and petroleum ownership, defining mineral resources as common heritage of all the people of South Africa, under the custodianship of the state [17,18].

In Civil Law jurisdictions, national legislation explicitly separates mineral from surface parcel ownership (Greek Mineral Code, art. 3; French Civil Code, art. 552; Spanish Civil Code, art. 339; Civil Code of Quebec, art. 951; Mining Act of Quebec, art. 3; Minerals Act of Sweden, Chap. 1, Sec. 1; Mining Act of Finland, Chap. 1, Sec. 2; Minerals Act of Norway, Sec. 7). Such ownership segregation may discriminate between specific minerals based on the state-owned and landowner distinction, or may indiscriminately comprise all types of minerals (e.g., Mining Act of Quebec, art. 3). State-owned minerals constitute individual real property objects (Greek Mineral Code, art. 65; Mining Act of Quebec, art. 9; Mineral Code of Louisiana, par. 18) and are subject to several mining rights such as prospections, exploration permits, mining leases and mining concessions.

In the event that constructions supporting mineral activities are required to be erected on the surface parcel, the use of surface land can be acquired through the establishment of servitudes, under appropriate compensation of the surface parcel owner. Servitudes can be established after agreement between the involved parties, administrative acts, court decisions or expropriation of the land parcel. However, mineral legislation in several countries, such as Brazil, Chile, Ecuador, Indonesia and Kazakhstan [19,20], does not provide for expropriation of surface parcel ownership. In such cases, the right to exploit surface parcel space is acquired under mandatory servitudes. In other jurisdictions (e.g., DR Congo, Ethiopia, Gabon, Ivory Coast, Portugal, Senegal, Peru, Uruguay), mineral concessions grant the concessionaire the right to use surface parcel by establishing administrative or mining servitudes, provided that the surface parcel owner is compensated [19,20].

In Common Law jurisdictions, land ownership initially included subsurface minerals. However, over the years, protection of public interest along with the extensive areas held under state or crown ownership have resulted in the state/crown retaining mineral ownership when alienating land to individuals, while mineral legislation mostly focused on regulating mineral leases over public lands, also imposing obligations of public concern on mining activities (Wälde, 1988, according to [17]).

Different types of licenses or mining tenements can be established, conferring different rights on their holders and applying for different durations. One of the most significant characteristics of Australian mineral legislation is its provision for stratification of mineral real property units. The Victorian Mineral Resources (Sustainable Development) Act (1990) provides that licenses scan be granted for a stratum of land, using the same definition of a "*stratum of land*" with that of the Transfer of Land Act of Victoria, to define its 3D real property units as "*a part of land consisting of a space of any shape below, on or above the surface of the land or partly below and partly above the surface of the land, all of the dimensions of which are limited*" (Victoria, Mineral Resources (Sustainable Development) Act (1990) Sec. 4).

In the United States, the General Mining Law (1872), declares all valuable mineral deposits in federal lands of the United States free and open to exploration and purchase, and such lands open to occupation and purchase (Sec. 2319). The locator of a mineral deposit can either be entitled to an exclusive possessory interest in surface and subsurface lands, and the right to develop the minerals (unpatented mining claim), or acquire the title of land from the federal government (patented mining claim) [21,22].

2.1.2. Cultural Heritage Restrictions

Cultural heritage is a collective term that encompasses archaeological sites, monuments and intangible cultural heritage. Cultural heritage sites may refer to marine or terrestrial antiquities, while the latter can be traced on the ground (e.g., historical sites or monuments), or may be buried below the ground. In both cases, protection measures are stipulated in legislation, either to preserve antiquities, or to assess and mitigate the impact of planned structures and developments on the landscape, the character or the view of a region where a monument, landmark or historical site is situated. Depending on each historical period, heritage remains vary, from earthworks (for example, burial mounds, hillforts and field banks), to buildings (e.g., buildings, canals, bridges and roads), or artefacts [23]. Underground archaeological treasures are in many cases combined with surface cultural and archaeological sites (e.g., Greece), as shown by [24], or are exploited for tourist, underground parking or recreational purposes. [25] present characteristic cases of the development of underground spaces' exploitation in London and New York, while [26] display similar cases applying to the ancient caverns below the city of Naples, dating from the Greek and Roman periods.

Cultural heritage objects are strongly related to their location, reflecting their integration with local environment specifications, emanating their distinctive character and "spirit". To this aim, it is preferred by the responsible authorities that archaeological and other cultural heritage resources are not removed from their location. This also accords with the prevalent philosophy on preservation of underground archaeological resources, which opts for leaving archaeological resources intact to be exploited by future generations, with more efficient and safer methods [27]. Consequently, the solution of establishing buffer zones around cultural heritage sites, on which protection restrictions apply, is encouraged. Operational Guidelines for the Implementation of the World Heritage Convention explicitly provide for the establishment of buffer zones in case of World Heritage properties [28]. Within this context, a buffer zone is defined as "an area surrounding the nominated property which has complementary legal and/or customary restrictions placed on its use and development to give an added layer of protection to the property. This should include the immediate setting of the nominated property, important views and other areas or attributes that are functionally important as a support to the property and its protection. The area constituting the buffer zone should be determined in each case through appropriate mechanisms. Details on the size, characteristics and authorized uses of a buffer zone, as well as a map indicating the precise boundaries of the property and its buffer zone, should be provided in the nomination" [27]. Although the buffer zone is not explicitly defined in 3D in this definition, its volumetric character is inferred, either through the reference on 3D characteristics, such as views, or by the stipulation of other areas or attributes that are functionally important to the support and protection of heritage sites. Stipulations on the establishment of horizontally delimited heritage protection buffer zones can be traced in the legislation of several jurisdictions (among others, Greece, the United Kingdom, Romania, Norway, Sweden, Denmark and Slovenia) [29–32], Law 3028/2002, SFS 1988:950; Cultural Heritage Act, 1978. Buffer zones do not set a volumetric protection zone around a site. Instead, they are defined as radial distances around the site, where specific restrictions or regulations apply. However, separate volumetric restrictions are imposed on land by specific legislation, especially in the case of underground antiquities; for example, Athens' subway line in Greece was developed at a depth starting from 15 metres below the Earth's surface [24] to protect layers of archaeological interest lying above. Therefore, two stratified volumes are created: A volume where construction is restricted due to the existence of underground antiquities, and a second volume where construction of the subway line is developed.

Common cultural heritage-related restrictions with vertical connotation, traced in the literature [4,33–35], follow:

- 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.
- Land parcel expropriation.
- Restrictions in real estate property uses concerning those that may destroy or harm the monument directly, or indirectly, as well as restrictions on 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.
- Preservation of cultural heritage objects in situ by (i) rerouting of planned developments, (ii) integration of cultural heritage objects to the design of a planned development as an open or recreational space, (iii) agreeable level of cultural heritage object's destruction.
- Vertical circumvention of cultural heritage objects by constructing a planned development at a deeper or lower level.

2.1.3. Environmental-Related Restrictions

Environmental legislation does not define the environment merely as natural characteristics of human surroundings, such as soil, air and water. In most developed countries, the concept of environment incorporates physical resources, ecosystems and landscapes, as well as social, economic and cultural conditions, monuments and historic areas [12].

The physical environment comprises geology, soils, land, hydrology, surface and ground water resources, air and noise, landscape and visual amenity. Each of these components are interrelated and pertain to 3D characteristics, while environmental protection legislation stipulates restrictions or regulations that can be explicitly defined in 3D (such as restrictions in height, depth or volume), restrictions or regulations that may apply to 3D space but are defined by non-geometrical 3D characteristics (such as soil characteristics in the case of groundwater protection) and implied 3D restrictions or regulations, which are based on non-quantifiable characteristics (e.g., aesthetics), such as landscape view [36].

The biological environment includes vegetation, wildlife, habitats and protected or conservation areas traced on terrestrial, freshwater, coastal or aquatic environments. Considering the components of the biological environment, only protected areas seem to be relevant to 3D PLRs. However, protection of vegetation and wildlife imposes 3D restrictions. Vegetation defines the landscape form and constitutes the habitat of specific types of fauna, while also affects water runoff, soil stability and resistance to erosion [37–40]. Therefore, changes in vegetation usually result in 3D impacts, thus defining vulnerable volumes due to soil instability or flooding, which require protection measures. There are also 3D restrictions related to wildlife, given that different species reside at specific altitudes, or a specific depth below the land surface (or the sea level), while bird migration routes also constitute 3D zones, which can be used to impose protection measures.

The socio-economic environment extends to a variety of fields that reflect lifestyle, cultural characteristics, community characteristics, quality of life and health conditions in a region, along with their relation and impacts on the bio-physical environment [41]. Among the abundance of socio-economic parameters, those pertaining to 3D characteristics and that can be used within a 3D PLR context are those related to land tenure and land use, as well as infrastructures and public services [42]. The latter include all roads, harbours, airports and railways, as well as all types of networks such as water and sanitation, irrigation, waste management, energy and telecommunications. Most of these networks are developed above or below the Earth's surface and their operation and maintenance imply specific regulations, regarding access, security, potential overlaps with other infrastructures, protection zones or other types of zones, defined by public law. Such regulations affect land tenure and land use by limiting the vertical extent of land exploitation, or by imposing specific land use types.

2.1.4. Civil Aviation-Related Restrictions

Aviation constitutes one of the most common conflicts between the vertical extent of the right of ownership, as defined in the Roman maxim "cujus est solum, ejus est usque ed ad coelom ed ad inferos [1]", with the passage of air vehicles above real property. Such conflicts were soon resolved either through court decisions, or by legal amendments. At the international level, international agreements were established, e.g., the International Air Services Transit Agreement [43], in favour of facilitating air transport, on the condition that flights do not impede the land parcel owner's enjoyment of the land [44]. Civil aviation restrictions can be further distinguished into restrictions on constructions' height, applying to the vicinity of airports, and on flight restrictions on manned or Unmanned Air Vehicles (UAVs).

Restrictions on the height of constructions, applying in the vicinity of airports, or physical object height restrictions applied in the areas surrounding airports, as well as volumetric requirements within the area of an airport, are imposed, to ensure safe take-off and landing of air vehicles. The International Civil Aviation Organisation (ICAO) has developed standards and recommended practices defining restriction zones or height limitations, while research towards generation of 3D electronic Terrain and Obstacle Databases (eTODs) is conducted by exploiting the variety of data acquisition techniques. Requirements for airspace around aerodromes, free from obstacles, are stipulated in ICAO documentation.

Obstacles are defined as "All fixed (whether temporary or permanent) and mobile objects, or parts thereof, that: (a) are located on an area intended for the surface movement of aircraft; or (b) extend above a defined surface intended to protect aircraft in flight; or (c) stand outside those defined surfaces and that have been assessed as being a hazard to air navigation" [45]. The allowed volume of obstacles is delineated by Obstacle Limitation Surfaces (OLSs). According to ICAO, OLSs are "conceptual (imaginary) surfaces associated with a runway, which identify the lower limits of the aerodrome airspace above which objects become obstacles to aircraft operations" [46]. The ICAO [47] distinguishes the following types of OLS, also shown in Figure 1:

- Outer horizontal surface: "A plane located 150 m above the aerodrome elevation datum and extending from the upper edge of the extended conical surface for a distance of 50,000 m (radius) from aerodrome reference point (ARP)" [48].
- Conical surface: "A surface sloping upwards and outwards from the periphery of the inner horizontal surface" [47].
- Inner horizontal surface: "A surface located in a horizontal plane above an aerodrome and its environs" [47].
- Approach surface: "An inclined plane or combination of planes preceding the threshold" [47].
- Inner approach surface: "A rectangular portion of the approach surface immediately preceding the threshold" [47].
- Transitional surface: "A complex surface along the side of the strip and part of the side of the approach surface, that slopes upwards and outwards to the inner horizontal surface" [47].
- Inner transitional surface: "A surface similar to the transitional surface but closer to the runway" [47].
- Balked landing surface: "An inclined plane located at a specified distance after the threshold, extending between the inner transitional surface" [47].
- Take-off climb surface: "An inclined plane or other specified surface beyond the end of a runway or clearway" [47].

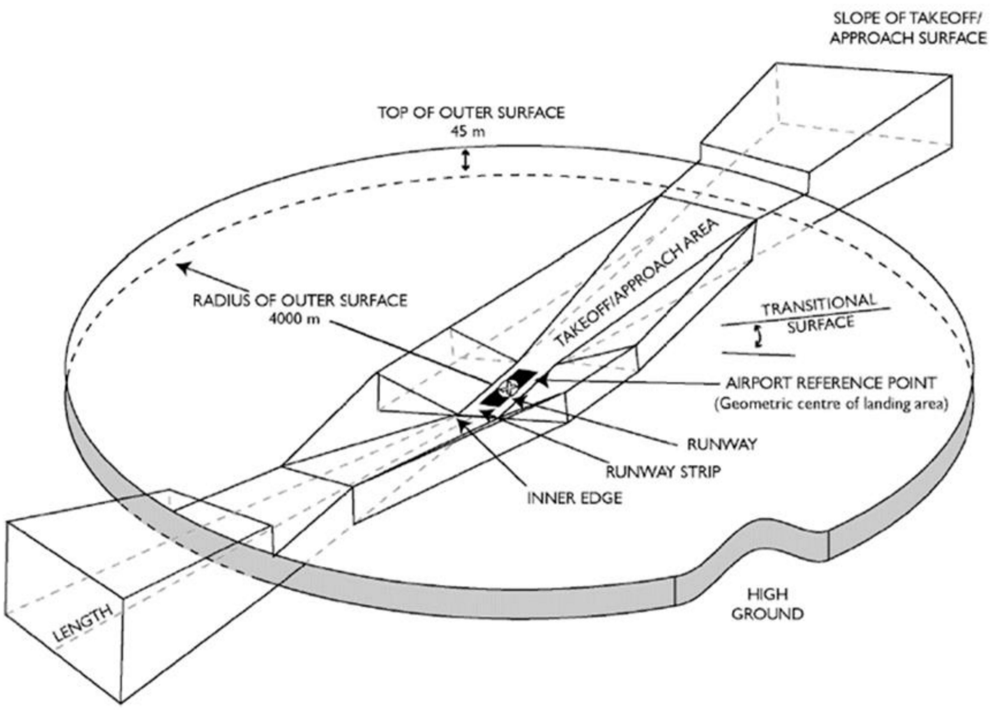

Figure 1. Obstacle Limitation Surfaces (OLSs) [49].

Apart from the abovementioned zones, vertical restrictions are also imposed on the installation of telecommunications and electronic systems, to secure the proper operation of navigational aids, radars and telecommunication systems. Therefore, radar coverage volumes are defined, imposing regulations on the size and materials of constructions. Precise regulations can only be defined in case-specific situations, based on the specifications of each aerodrome's location, e.g., topography, or type of a proposed structure [49].

Until the early 2000s, flight restrictions referred to the definition of temporary or permanent no-flight zones, almost exclusively applying to manned air vehicles, such as propeller aircrafts or jets, defined by planar coordinates, e.g., easting/northing, and their vertical extent, by reference to the Mean Sea Level (MSL). However, the growing use of Unmanned Air Vehicles (UAVs) for commercial purposes has led to the introduction of legislation regulating UAV flights. The relatively low flight height of UAVs, their affordability and their increasing operational capabilities introduce issues of privacy, data protection and public safety [50,51], such as the protection of the public or aboveground infrastructures (e.g., powerlines).

According to the literature, the most common flight restrictions imposed are the following [51–55]:

- Definition of minimum low-flying height, based on the type and the population of the overflying area.
- Definition of minimum vertical distance between the highest obstacle of the area and the flight zone.
- Definition of specific flight conditions depending on the UAV's weight.
- Restrictions based on visibility conditions and visual contact with a UAV during its navigation.

2.1.5. Spatial and Urban Planning Restrictions

Regulations on spatial and urban planning were firstly introduced in European legislation in the early twentieth century [56]. Such regulations were introduced during the same period in the United States and Canada [57,58]. In the highly populated Chinese cities, especially the so-called Treaty Ports, planning regulations can be traced to around the middle of the nineteenth century [59]. Regulations to ensure the stability of constructions, fire prevention and drainage can be traced to the end of the eighteenth century (e.g., United Kingdom's Public Health Act of 1875, [25]).

Urban planning and construction regulations are imposed by legal instruments, issued by different administrative bodies, based on the administrative organisation of each country. Urban planning-related PLRs regulate several fields such as land use, major infrastructures and developments, implementation of special economic policies, transport, education, energy consumption, public investments, environment and traditional architecture preservation.

Among the most significant urban planning regulations with 3D aspects is zoning [57,60]. Zoning regulations define regions where different pollution, health and land use requirements apply, thus determining volumes of space that can be exploited and the type of their exploitation, while setting volumetric or height restrictions to protect or mitigate pollution.

Emissions 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 to [61]). Each of the abovementioned emissions includes 3D aspects, although at different levels, which can be used to define emissions falling into the field of 3D PLRs.

EU Directive 2002/49 already provides for the compilation of noise maps and strategic noise maps (art. 4) referring to specific heights for noise indication measurements. Given its 3D propagation, noise regulations can be managed more efficiently through 3D representations [9]. Although 3D data such as building heights, noise barriers and topography are taken into account for noise calculation, in most cases 2D noise maps are compiled, limiting insight to the 3D aspects of noise [62]. To this aim, research towards generation of 3D noise maps is conducted, including 3D noise maps of the cities of Paris [63], Delft [62] and Hong Kong [64] and the state of North Rheine-Westphalia in Germany [65]. Public Law also regulates issues related to radio wave propagation to ensure efficient communication and broadcasting as well as to protect public health and the 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 on their distance from specific sites, frequency range and antenna tower heights [66].

Regulations on building height for visibility purposes also constitute an urban planning-derived PLR. There are various restrictions applying to the urban landscape in order to protect landmarks and their visibility, e.g., London View Management Framework [67].

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

Additionally, for the protection of the urban landscape, specific building regulations apply, for example, to protect traditional architectural characteristics of buildings, e.g., facades, or to protect the architectural character of a neighbourhood. Construction regulations with 3D characteristics can be summarised as the following [36,57,60,68–71]:

- Built surface ratio: The permitted building surface in an area, deriving from the maximum building height and the building coverage ratio.
- Maximum building height: The highest level of a construction. Maximum building height sets the upper limit of a land parcel's exploitation.
- Building volume coefficient: The maximum volume within a land parcel that is allowed to be covered by a construction.
- Building coverage ratio: The area of a land parcel that can be covered by a construction. Therefore, it directly affects the height, the volume and the shape of an intended structure.
- Transfer of built surface ratio (in some jurisdictions also known as transfer of development rights): Transferring of non-depleted built surface to another land parcel.
- Noise protection: Regulations for the minimisation of noise impacts.
- Flooding limits: Minimum height of the entrance and the floor level to avoid flooding.
- Impact on significant views, sightlines or landscapes.
- Impact on cultural heritage or architectural characteristics of the neighbouring area.
- Buildings' lighting, ventilation and solar exposure.

2.1.6. Restrictions Relating to Utility Networks

Utilities also result in overlapping rights in 3D space. Characteristic cases of utilities are aerial and underground networks, or other major infrastructures, such as underground subway lines, tunnels, pipelines or underground storage volumes. Volumetric restrictions need to be imposed for the protection of the utility and for public safety. Conversely, similar restrictions need to be imposed based on the potential impact of a planned underground construction on surface parcels and their elements; for example, the impact of vibration deriving from the construction and the operation of an underground subway line on the foundations of the buildings on its overlying land parcels.

There are numerous examples of utilities above or below ground in urban and rural environments traced in the literature [4,42,72,73]. In Finland, an Underground Master Plan (UMP) has already been developed for the city of Helsinki [74], while plans of underground space exploitation are also in progress for the other Finnish cities, such as Tampere and Oulu [75]. Underground space development to promote urban renewal of the city of Tokyo has been proposed by [76], while it is already operational in several countries for, inter alia, storage, waste treatment, storage of explosives, sewage and wastewater treatment purposes [77,78].

The space for the deployment of utilities is acquired by the agencies responsible for the operation of each utility through land expropriation, establishment of utility servitudes (easements) or rights of way. Exceptions can be traced in jurisdictions where the vertical extent of individual land exploitation is stipulated by statute (e.g., Malaysia, Singapore, Japan, Victoria), or in jurisdictions allowing the formation of 3D real property units. In the former, the minimum depth of land exploitation by the surface parcel owners is defined, vesting the rest of the underground space to the state, while in the latter case, 3D volumes are "carved out" from the 3D parcel volumes, where the utility will be installed. In the case that an infrastructure is situated on public-owned land, a potential limitation is that there is no need for establishing limited, or other, real property rights, therefore the legal space of such an infrastructure is not visible in the cadastre [79–81].

The most common 3D restrictions related to the establishment and operation of public utilities are the following [4,81–84]:

- Depth restrictions on the exploitation of surface parcels, depending on the depth of underground infrastructures. Restrictions may relate to surcharge loads, excavations, pipelines and stores of combustible liquids and equipotential bounding.
- Building restrictions (height or depth limitations along the network's centreline).
- Cultivation restrictions (forbidding cultivation activities, or allowing cultivation types that root down to a specific depth).
- Volumetric restrictions along aerial powerlines both for powerlines' protection and to reduce radiation impacts.
- Establishment of a volumetric safety zone around utility networks to avoid damage in case of crossing networks.

2.2. PLRs' Technical Aspects and Standardisation Approaches

Regardless of if and how PLRs are organised, standardisation plays an important, though challenging, role in facilitating and enhancing information sharing, information integration and interoperability. In this arena, modelling of the people-to-land relationships, including the restrictions imposed by public law, as well as adopting core terminology, constitutes one of the main hindrances on 3D LAS legal research. Several researchers highlight this challenge [4,40,42,85–88], especially in the terminology-related aspects, in order to avoid misconceptions and maintain consistency.

In this domain, the ISO 19152:2012 Land Administration Domain Model (LADM) [89] provides a common terminology for LAS, allowing the modelling of RRRs, among others also intending to effectively include PLRs. Attention has been paid by [90,91] to the explicit modelling of PLRs both in Edition I and Edition II of the LADM, by providing various alternatives. Specifically, alternatives to model PLRs both in the administrative (legal) and the spatial package are introduced for both standard editions and compared using real-world cases. Furthermore, [92] provided a modelling alternative of RRRs deriving from Public Law in LADM Edition I, by proposing a refinement of the legal profiles presented in Annex F in LADM Edition I and creating a dedicated legal profile of restrictions, with a subclass to "LA_Restriction", named "LA_PublicLawRestriction".

Within this context, and in terms of standards regarding individual modelling of 3D objects (i.e., buildings, infrastructure objects, etc.) and not large-scale/nationwide coverage, such as OGC LandInfra, PLRs can be indirectly addressed through the "InterestInLand" class. Furthermore, the use of technical standards applicable to large-scale projects, such as OGC CityGML, has been examined for their applicability to model 3D PLRs. As CityGML aims to address the physical counterparts of 3D objects, there is no provision to explicitly model legal space, however, [36] have identified the CityGML modules and Application Domain Extensions (ADEs) that could be used to store such information. On the other hand, at the building level of modelling, research has been carried out to identify how legal information can be stored in ISO 16739 IFC, focusing mainly on buildings and limited to infrastructure objects, as they often have more complex geometries [93–96]. Similarly, OGC InfraGML [97], which is the GML encoding for LandInfra, is also project-based and allows the registration of both legal and technical information of infrastructure objects, without having specific provision of PLR-related information.

The need for reliable and consistent geoinformation at the national level, but also for individual properties, was significantly supported by appropriate technological tools to store, manage and visualise PLRs. Specifically, practice has shown that PLRs are organised and recorded in 2D databases and platforms, as they are mainly based on land legislation regarding the two-dimensional world, while there exist several technical complexities on the modelling and management side due to the large amount of data, with both quantitative and qualitative characteristics. 2D web-based visualisation platforms based on 2D databases have been developed nationwide and offer legally binding information about parcels, with the platform for PLRs cadastre in Switzerland being on the front line, as well as the Restrictions Information System from Estonia. In such systems, 2D GIS and CAD formats are being utilised and transformed accordingly.

Although the PLRs are being documented in 2D either in stand-alone databases or integrated with the operating LAS and visualised through geoportals, the nature of some of them is 3D, while their impact on 3D cadastres has been identified in the literature [10,36,82].

3. Discussion

This section discusses the literature review conducted in terms of the development of PLR-related legislation and literature over time, literature type and content. Literature sources reviewed along with their timeline are briefly presented in Table 2, while in Table 3 the various PLR categories are organised according to the data sources where they have been observed and the time period in which they have been documented.

The results from an analysis of the sources as categorised in Table 3 are presented hereafter.

Regarding mining and civil aviation, PLRs were the first restrictions with a direct three-dimensional connotation. Mineral legislation exists since there have been structures of public government, economic interest in minerals and the technical ability to extract them [17]. Similarly, since the invention of the airplane and the extensive uses of airspace for commercial and transportation purposes, airspace has been contested by landowners, airline companies and each state. In Civil Law jurisdictions, limitations to the Roman maxim on the extent of real property ownership, "He who owns the soil owns also to the sky and to the depths", were imposed, by introducing stipulations predicating the rights of landowners in height, up to the extent that their interests are affected [44]. In Common Law jurisdictions, the question on the extent of land ownership above a land parcel was first posed in 1946 (United States v. Causby) [98], and it has been discussed by several researchers [44,99,100].

Table 2. Literature time periods per source category.

Type	Time Periods			
	Before 1950	1951–2000	2001–2010	2011–2021
Statute [1]	2	5	11	11
Publication	-	9	13	37
Conference	-	-	7	13
Thesis	-	-	3	2
Other	-	-	2	1
Total number	2	15	37	64

[1] The development of legal statutes over time has not been examined. Only the number and the field of PLRs are included for the sake of completeness. Statutes include laws, regulations, ordinances, international guidelines, etc.

Table 3. PLR topics referenced per time period and data source.

Type	Time Periods/Topics			
	Before 1950	1951–2000	2001–2010	2011–2021
Statute [1]	i Mining ii Civil aviation	i Mining ii Civil aviation	i Mining ii Civil aviation	i Heritage ii Spatial planning iii Environment protection iv Utilities v Mining
Publication	-	i Civil aviation ii Heritage iii Spatial planning iv Environment protection	i Heritage ii Spatial planning iii Environment protection iv Utilities v Mining	i Heritage ii Spatial planning iii Environment protection iv Utilities v Mining vi Civil aviation
Conference	-	-	i Spatial planning ii Environment protection iii Mining iv Utilities	i Heritage ii Spatial planning iii Environment protection iv Utilities v Mining vi Civil aviation
Thesis	-	-	i Mining ii Environment protection	i Heritage ii Spatial planning iii Environment protection iv Utilities v Mining vi Civil aviation
Other	-	-	Heritage	Mining

[1] The development of legal statutes over time has not been examined. Only the number and the field of PLRs are included for the sake of completeness. Statutes include laws, regulations, ordinances, international guidelines, etc.

Furthermore, potential use of underground space in the Netherlands, from the multi-level exploitation of land, has already been proposed by [101]. Ref. [102] highlight the significance of the 3D/4D component for multiple use of land, while according to [103], planning thought and practice need to move beyond mere analysis of spatial patterns of activities organised in 2D space. Ref. [104] explore the benefits of using underground space to make cities more liveable, resilient and inclusive. Characteristic examples of country-specific studies on the exploitation of underground space and underground space planning can be traced for China [105], Japan [106], Russia [107] and Germany [108]. To this aim, [109] employ 3D WebGIS technology for the spatial planning support in Germany, developing a 3D WebGIS tool to identify underground spaces for compressed air energy storage.

The physical environment is a complex system of interrelated components that include soil, surface, groundwater, fauna, flora and landscape. Several of these components are not quantifiable, while their relations are not always clear and definable [42]. The requirements of environmental legislation for construction projects with significant environmental impact are reflected in Environmental Impact Assessment (EIA) studies, which incorporate all provisions on environment protection, as well as stipulations deriving from specific legislation such as mining, or archaeological laws. GIS systems are used to analyse and interpret all collected data and present relevant information using maps and charts. Currently, the use of 3D modelling in EIAs is limited to landscape analysis cases. The advantages of 3D modelling techniques in impact assessment are presented in several research works [110–112]. Ref. [113] also followed by concerns regarding technical requirements and data suitability [114,115].

PLRs imposed for cultural heritage protection are not considered as individual cadastral entities. If forming a part of cadastral registers, notification of the restriction is added to the involved/affected land parcels. Cultural heritage sites are in most cases registered to themed, archaeological, cadastres, either presenting in 2D the extent of heritage areas, or by point representations of monuments and landmarks. References to height, depth or volumetric restrictions are available only by reference to the legal document imposing them. Such restrictions have been identified by several researchers, investigating the exploitation of 3D cadastres for cultural heritage protection in various countries and jurisdictions. [4] present the three-dimensional characteristics of heritage protection, while [83] visualise archaeological protection 3D PLRs in Greece. Ref. [116] investigate the protection of structured cultural heritage in Turkey with 3D cadastres, through the legal instrument of a condominium, while [117] examines the advantages of 3D cadastres in cultural heritage preservation in Croatia.

Acquisition of space required for the development and maintenance of utilities is usually through land expropriation, establishment of utility servitudes (easements) or rights of way. In Common Law jurisdictions, implied easements and rights of way are mainly used, providing a flexible way to develop and access utility networks. However, implied easements are difficult to identify, as they are presented only through textual annotations on plans [118], while not appearing on cadastral [119]. Exceptions can be traced in jurisdictions where the vertical extent of individual land exploitation is stipulated by statute (e.g., Malaysia, Singapore, Japan, Victoria), or in jurisdictions allowing the formation of 3D real property units. In the former, the minimum depth of land exploitation by the surface parcel owners is defined, vesting the rest of the underground space to the state, while in the latter case, 3D volumes are "carved out" from the 3D parcel volumes, where the utility will be installed. In the case that an infrastructure is situated on public-owned land, a potential limitation is that there is no need for establishing limited, or other, real property rights, therefore the legal space of such an infrastructure is not visible in the cadastre [79–81].

PLRs within National Spatial Data Infrastructure

The research shows that PLRs are introduced within national spatial data infrastructures by being registered according to one of the following approaches:

- Integrated in cadastral systems.
- Maintained by an individual responsible authority.
- Development as "themed" cadastres, dedicated to specific types of PLRs (e.g., archaeological or utility cadastres).
- Development of a special registry for PLRs (PLR cadastre).

Integration of PLRs in the cadastre in order to clearly present the full legal situation on land has been discussed by several researchers [120–122]. The use of cadastral parcels as the background of PLRs is considered reasonable, given that land parcels constitute the basic registration unit of cadastral systems, in order to be informed on the imposed rights, restrictions and responsibilities [121]. In the Netherlands, PLRs constitute an individual dataset of the Dutch geoinformation platform, including restrictions deriving from the Heritage Act, municipal and provincial provisions, environmental regulations (such as provisions of the Nature Conservation Act, the Environmental Law, the Groundwater Act, the Soil Protection Act or the Air Protection Act), spatial planning and aviation prohibition. However, there are also several types of restrictions, such as the drone "no-flight zones" that are maintained as individual datasets, apart from the PLR section, such as spatial plans. Similar integrated portals can be traced both in Europe and internationally, e.g., Finland, Norway, Serbia, Canada. PLRs are either planar or point representations followed by reference to the legal instrument imposing a restriction. However, there are a number of restrictions deriving from the existence of specific objects, for example, a protection zone around an underground utility. Although the objects related to a restriction are registered, the corresponding restriction is often not registered or shown on the map.

PLRs may also be held by the organisation that imposes them or is responsible for their implementation, such as ministries, agencies or municipalities. This also includes restrictions deriving from the existence of an object, e.g., protection zones around an underground pipeline. Depending on each organisation, such information may be openly accessed by the public, or available only to interested parties. This relates to the concept of “themed” cadastres, on which specific types of PLRs are registered.

Archaeological cadastres and utility cadastres constitute the most common cases of themed PLR cadastres (e.g., Greek Archaeological Cadastre, Cultural Heritage application of the Estonian Land Board Geoportal, Utility Cadastre of Serbia, Register of Public Service Networks in the province of Quebec in Canada). Moreover, registries of environmental information such as forest protection zones, litter and contamination are made available by the Department of Environment, Land, Water and Planning of the state of Victoria in Australia, while registries on the protection of Aboriginal cultural heritage are also available in several Australian states (Aboriginal Cultural Heritage Register and Information System in Victoria, State Heritage Inventory of New South Wales, Cultural Heritage Register and database of Queensland). The main disadvantage of such registries is that they mainly emphasise specific objects, for example, archaeological antiquities or utilities, rather than the restrictions deriving from the existence of such objects imposed on individual properties [4].

The most innovative approach to PLR registration is followed in Switzerland, where cantonal PLR cadastres are operational for almost all cantons of Switzerland. The PLRs which were considered to be most important were selected to be included in the new registry [123]. Currently, Swiss PLR cadastres record seventeen types of PLRs, classified in eight areas, while another twenty are considered to enrich the PLR cadastre structure [124]. Currently, restrictions related to contaminated sites, railways, airports, groundwater protection, noise, motorways, spatial planning and forests are included in the Swiss PLR cadastre, whereas restrictions related to power supply are under preparation to be added by 2023 [125]. An extract of the PLR cadastre includes a map showing the area on which a restriction is imposed, the legal provisions applying to the examined land parcel, as well as the legislation imposing each restriction [126].

Regardless of such provisions, the three-dimensional aspect of PLRs remains partially addressed, as all restrictions are literally described, while their spatial extent remains restricted on planar field representations. Therefore, several researchers have proposed the use of 3D models for modelling infrastructures [79,127], protection of cultural heritage and traditional settlements [83], geoheritage management [128], environmental applications and environmental impact assessment studies [62,110,111,129,130]. Three-dimensional modelling is considered to provide flexibility in planning options for policymakers and professionals, as well as more effective visual representation, thus fostering public participation in environmental consultation [115]. However, there are several aspects that need to be taken into account when applying 3D modelling to physical environment modelling, such as the level of detail of the developed models, the cost, system architecture requirements, data accuracy, scale consistency and the reliability and accountability of the resulting 3D models [114,115]. Limitations of 3D physical environment modelling have a lesser impact on 3D modelling of PLRs since modelling of PLRs merely requires the development of simple geometrical volumes on which restrictions apply, that can be developed by 2D coordinates and corresponding height, depth or volumetric characteristics of each PLR [42].

4. Conclusions

The paper discusses how the restrictions from Public Law are being inspected and organised, considering their characteristics and classification, their modelling and management options, level of integration within existing LASs, their 2D and/or even 3D extent, as well as the law family they relate to, based on a literature survey.

Based on existing knowledge and statutory legislation, covering an international context, and considering publications in well-recognised research sources and proceedings in international events, this paper provides an overview regarding the legal and technical aspects of the Public Law restrictions within the context of 3D land administration. Determining the extent of the PLRs on landownership is important, not only for landowners, but also for public administrators, developers and players on the mortgage market, as well as (urban and spatial) planners, as they become aware of the limitations and potential of real property, in order to efficiently exploit it by complying with the regulations imposed by the public law.

Coming to the first research question referring to the legal statutes imposing PLRs, it seems that the various types of restrictions that arise from Public Law involve many legislative processes, mainly related to administrative regulations, urban planning, environmental protection, aerial/subsurface space exploitation, as well as water/coast protection and protected sites. Although most restrictions are documented in 2D, sometimes the third dimension is required to better describe the restriction's impact on the 3D space. From the research, it is concluded that there are multiple and different organisations and authorities that are responsible for the management and maintenance of PLRs, which operate under different legal and technical statuses, and priorities. Furthermore, a broad range of PLR fields (based on geometrical, non-geometrical, implied 3D characteristics) occur in the majority of countries, and there is no pattern identified for their organisation, and their selection for their registration is mainly arbitrary and based on national LAS priorities. Hence, their organisation options vary from independent maintenance in stand-alone databases by each responsible authority, the development of "themed" cadastres dedicated to specific types of PLRs (e.g., archaeological or utility cadastres) or the development of an individual registry where all the PLR types are organised (PLR cadastre), to an integrated system, where PLRs are incorporated into the national LAS, or even hybrid solutions. From the research carried out, it remains an open question whether 3D PLR models are authoritative or informative. Regarding the 3D characteristics used to define the vertical extent of PLRs, a broad range of parameters are used, including (ideally, yet less commonly) reference to volumetric characteristics (e.g., depth, height or volume), reference to non-geometrical characteristics (e.g., physical or geological characteristics) or reference to qualitative parameters (e.g., aesthetics). This affects the technical aspects of modelling and visualising PLRs in 3D, as both non-geometrically and qualitatively defined PLR characteristics need to be quantified in volumetric terms, thus introducing issues of accuracy and legal validity of the developed models.

Coming to the second research question, from a technical point of view, which bridges many different legal approaches, it seems that PLRs have not been investigated individually from other RRRs within an LAS. From the developments to date, the 2D web visualisation platforms are those which are the most common, as they allow for visualisation, querying and dissemination of the information. Classification of PLRs, as examined in the second research question, varies depending on the aim of each study. In this work, PLRs are classified based on thematic categories (shown in Table 1), in order to avoid an exhaustive, highly complicated enumeration of the abundance of land-related 3D PLRs. Within the context of 3D city modelling, various digital technologies and tools (e.g., artificial intelligence and digital twins) may be used to visualise PLRs, providing explicit information about the parcels' legal status, although not reported in this literature research. Finally, the research showed that standardisation studies on PLR modelling are quite limited, with the developments related to their modelling within LADM playing a dominant role. However, it appears that standards are important in all stages of registering, organising, integrating, visualising, querying and disseminating PLR-related information, both in 2D and 3D, and a suggested area for further research in this field.

Author Contributions: Conceptualization, D.K.; methodology D.K., E.D.; investigation, D.K., E.K. (technical aspects and standardization approaches); writing—original draft preparation, D.K., E.K.; writing—review and editing, D.K., E.K., E.D.; visualization, D.K.; project administration, D.K., E.D. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.

Note

[1] He who owns the soil owns also to the sky and to the depths (Translation from Latin by [77]).

References

1. Agalopoulou, P. *Basic Concepts of Greek Civil Law*; Masry Kotsovou, Y., Ed.; Stämpfli: Bern, Switzerland, 2005.
2. Martin, E. (Ed.) *A Dictionary of Law*, 5th ed.; Oxford University Press: Oxford, UK, 2003.
3. Georgiadis, A. *Handbook of Property Law*, 2nd ed.; Sakkoulas Publications: Athens, Greece, 2012.
4. Kitsakis, D.; Dimopoulou, E. Possibilities of Integrating Public Law Restrictions to 3D Cadastres. In *5th International FIG 3D Cadastre Workshop*; Van Oosterom, P., Dimopoulou, E., Fendel, E.M., Eds.; International Federation of Surveyors: Copenhagen, Denmark, 2016; pp. 25–46.
5. Cadastre and Land Registry Knowledge Exchange Network. *Documentation of "Public—Law Restrictions"*; Eurogeographics: Brussels, Belgium, 2015.
6. Crawford, C. The Social Function of Property and the Human Capacity to Flourish. *Fordham Law Rev.* **2011**, *80*, 1089–1134. Available online: http://ir.lawnet.fordham.edu/flr/vol80/iss3/5 (accessed on 20 November 2021).
7. Spyridakis, I.N. *Real Property Law I*; Ant N Sakkoulas Publishers: Athens, Greece, 2001.
8. Rosenfeld, M. Rethinking the boundaries between public law and private law for the twenty first century: An introduction. *Int. J. Const. Law* **2013**, *11*, 125–128. [CrossRef]
9. Givord, G. Cadastre 3D des restrictions de droit public à la propriété foncière. Ph.D. Thesis, Conservatoire National des Arts et Métiers, Paris, France, 2012.
10. Navratil, G. Combining 3D Cadastre and Public Law—An Austrian Perspective. In Proceedings of the 3rd International Workshop on 3D Cadastres, Shenzhen, China, 25–26 October 2012; pp. 61–72.
11. Bennett, R. *Property Rights, Restrictions and Responsibilities: Their Nature, Design and Management*; The University of Melbourne: Melbourne, Australia, 2007.
12. Kitsakis, D. *Legal Requirements for Real Property Stratification*; National Technical University of Athens: Athens, Greece, 2019.
13. Hopper, R.J. The Mines and Miners of Ancient Athens. *Greece Rome* **1961**, *8*, 138–151. [CrossRef]
14. Ovesná, G.; Staňková, H.; Plánka, L.; Wlochová, A. The history of mine surveying and mining maps. *Geod. Cartogr.* **2017**, *43*, 118–123. [CrossRef]
15. World Ocean Review. *World Ocean Review 4: Clean Production and Equitable Distribution*; Maribus gGmbH: Hamburg, Germany, 2014.
16. Herber, B. The Common Heritage Principle: Antarctica and the Developing nations. *Am. J. Econ. Sociol.* **1991**, *50*, 391–406. [CrossRef]
17. Liedholm Johnson, E. *Mineral Rights: Legal Systems Governing Exploration and Exploitation*; Royal Institute of Technology (KTH): Stockholm, Sweden, 2010. Available online: https://www.kth.se/polopoly_fs/1.131782!/Menu/general/column-content/attachment/FULLTEXT01(2).pdf (accessed on 21 November 2021).
18. Cawood, F.T. The Mineral and Petroleum Resources Development Act of 2002: A Paradigm Shift in Mineral Policy in South Africa. *J. S. Afr. Inst. Min. Metall.* **2004**, *104*, 53–64.
19. Globalaw International Law Group. *Basics of Mining Law—Selected Jurisdictions*; Global Legal Group Ltd.: London, UK, 2016.
20. ICLG. *The International Comparative Legal Guide to: Mining Law 2019*; Global Legal Group Ltd.: London, UK, 2019.
21. Kahalley, K.L.; Nichols, K.A.; Bassett, R.A. United States. In *The Mining Law Review*; Law Business Research Ltd.: London, UK, 2016; pp. 232–242.
22. La Flèche, E.R. (Ed.) *The Mining Law Review*, 5th ed.; Law Business Research Ltd.: London, UK, 2016.
23. Braithwaite, R.; Hopkins, D.; Grover, P. Archaeological and other material and cultural assets. In *Methods of Environmental Impact Assessment*, 2nd ed.; Morris, P., Therivel, R., Eds.; Spon Press: London, UK, 2005; pp. 122–144.
24. Papageorgiou, M. Networking underground archaeological and cultural sites: The case of Athens metro. In *Think Deep: Planning, Development and Use of Underground Space in Cities*; Admiraal, H., Shipra, N.S., Eds.; Drukkerij Aktief: Pijnacker, The Netherlands, 2015; pp. 54–70.
25. Reynolds, E.; Reynolds, A. Planning for underground spaces "NY-LON" underground. In *Think Deep: Planning, Development and Use of Underground Space in Cities*; Admiraal, H., Shipra, N.S., Eds.; Drukkerij Aktief: Pijnacker, The Netherlands, 2015; pp. 34–54.
26. De Stefano, V.; di Pinto, V.; Gerundo, C. Naples and its parallel city. In *Think Deep: Planning, Development and Use of Underground Space in Cities*; Admiraal, H., Shipra, N.S., Eds.; Drukkerij Aktief: Pijnacker, The Netherlands, 2015; pp. 34–54.
27. Marriott, B. *Environmental Impact Assessment: A Practical Guide*; McGraw-Hill: New York, NY, USA, 1997.
28. UNESCO. Operational Guidelines for the Implementation of the World Heritage Convention. WHC.17/01. 2017. Available online: http://whc.unesco.org/en/contacts (accessed on 1 December 2021).
29. Badea, G.; Badea, A.-C. Current issues in cadastral regulations in Romania. In Proceedings of the World Cadastre Summit 2015, Istanbul, Turkey, 20–24 April 2015.
30. The Agency for Culture and Palaces. Protected Sites and Monuments. 2019. Available online: https://slks.dk/english/work-areas/cultural-heritage/sites-and-monuments/protected-sites-and-monuments/ (accessed on 25 November 2021).

31. Historic England. The Protection Management of World Heritage Sites in England. 2015. Available online: https://historicengland.org.uk/images-books/publications/protection-management-of-world-heritage-sites-in-england/englishheritagewhsplanningcircularguidance/ (accessed on 20 November 2021).
32. Pirkovic, J. Concept of Cultural Heritage Protection and Management in Slovenia. Shared Global Experiences for Protection of Built Heritage. 2017, pp. 12–19. Available online: https://openarchive.icomos.org/id/eprint/2205 (accessed on 25 November 2021).
33. Australian Heritage Commission. *Protecting Local Heritage Places: A National Guide for Local Government and the Community*; Australian Heritage Commission: Canberra, Australia, 2009.
34. Bourdillion, N.; Braithwaite, R.; Hopkins, D.; France, R. Archaeological and Other material and cultural Assets. In *Methods of Environmental Impact Assessment*; Morris, P., Therivel, R., Eds.; UCL Press: London, UK, 1995; p. 380.
35. Draye, A.M. Legal protection of monuments in their settings: A means of maintaining the spirit of the place. In *16th ICOMOS General Assembly and International Symposium*; ICOMOS: Quebec City, QC, Canada, 2008; p. 11.
36. Kitsakis, D.; Kalantari, M.; Rajabifard, A.; Atazadeh, B.; Dimopoulou, E. Exploring the 3rd dimension within public law restrictions: A case study of Victoria, Australia. *Land Use Policy* **2019**, *85*, 195–206. [CrossRef]
37. Cafuzzi, D.; Crippa, E. Contribution of Vegetation to Slope Stability: An Overview of Experimental Studies Carried Out on Different Types of Plants. In *Erosion of Soils and Scour of Foundations*; Geo-Frontiers Congress: Austin, TX, USA, 2005.
38. Environmental Protection Authority. *Environmental Factor Guideline Flora and Vegetation*; Environmental Protection Authority: Joondalup, Western Australia, Australia, 2016.
39. Mabuchi, K.; Sato, Y. Climatic Impact of Vegetation Change in the Asian Tropical Region. Part I: Case of the Northern Hemisphere Summer. *J. Clim.* **2005**, *18*, 410–428. Available online: https://journals.ametsoc.org/doi/pdf/10.1175/JCLI-3273.1%0A (accessed on 22 November 2021). [CrossRef]
40. Sulaiman, S.; Mohamad, N.H.N.; Idilfitri, S. Contribution of Vegetation in Urban Parks as Habitat for Selective Bird Community. *Procedia Soc. Behav. Sci.* **2013**, *85*, 267–281. [CrossRef]
41. Rutz, D.; Janssen, R. Socio-economic impacts of biofuels on land use change. In *Socio-Economic Impacts of Bioenergy Production*; Rutz, D., Janssen, R., Eds.; Springer International Publishing: Cham, Switzerland, 2014; pp. 81–93. [CrossRef]
42. Kitsakis, D.; Dimopoulou, E. Determining the "true" three-dimensional environmental impact of Public Law Restrictions. In *6th International FIG 3D Cadastre Workshop*; Van Oosterom, P.J.M., Fendel, E.M., Eds.; International Federation of Surveyors, Delft University of Technology: Delft, The Netherlands, 2018; pp. 291–308.
43. ICAO. *International Air Services Transit Agreement*; ICAO: Montreal, QC, Canada, 1944.
44. Abramovitch, Y. The maxim "Cujus est solum ejus usque ad coelum" as applied in aviation. *McGill Law J.* **1953**, *8*, 247–269.
45. ICAO. *Aerodromes*; ICAO: Montreal, QC, Canada, 2016.
46. Aerosafe Risk Management. *Man Made Obstacles Located Away From Aerodromes Risk Review*; Aerosafe Risk Management: New South Wales, Australia, 2009.
47. ICAO. *Aerodromes*; ICAO: Montreal, QC, Canada, 2009; Volume I.
48. Qiao, X.; Lv, S.H.; Li, L.L.; Zhou, X.J.; Wang, H.Y.; Li, D.; Liu, J.Y. Application of DSM in obstacle clearance surveying of aerodrome. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2016**, *41*, 227–233. [CrossRef]
49. Flight Standards Division. Land Use In The Vicinity of Aerodromes. 2013. Available online: https://www.tc.gc.ca/eng/civilaviation/publications/tp1247-menu-1418.htm (accessed on 19 November 2021).
50. Finn, R.L.; Wright, D.; Jacques, L.; de Hert, P. *Study on Privacy, Data Protection and Ethical Risks in Civil Remotely Piloted Aircraft Systems Operations*; European Commission: Brussels, Belgium, 2014. [CrossRef]
51. Stöcker, C.; Bennett, R.; Nex, F.; Gerke, M.; Zevenbergen, J. Review of the current state of UAV regulations. *Remote Sens.* **2017**, *9*, 459. [CrossRef]
52. FAA. *Proposed Construction or Alteration of Objects that May Affect the Navigable Airspace*; US Department of Transportation: Washington, DC, USA, 2000.
53. FAA Guide to Low-Flying Aircraft, 39. 2008. Available online: https://www.faa.gov/about/office_org/field_offices/fsdo/lgb/local_more/media/FAA_Guide_to_Low-Flying_Aircraft.pdf (accessed on 19 November 2021).
54. ICAO. *Manual on Remotely Piloted Aircraft Systems (RPAS)*; ICAO: Montreal, QC, Canada, 2015.
55. Secretary of State for Transport (UK). *The Rules of the Air Regulations 2007*; Secretary of State for Transport (UK): London, UK, 2007; No. 734. [CrossRef]
56. Albrechts, L. Strategic (spatial) planning reexamined. *Environ. Plan. B Plan. Des.* **2004**, *31*, 743–758. [CrossRef]
57. Dinic, M.; Mitkovic, P. Planning regulations in the USA and their implications on urban design in the central city zone. *Facta Univ. Ser. Archit. Civ. Eng.* **2011**, *9*, 289–299. [CrossRef]
58. Hulchanski, J.D. *The Evolution of Ontario's Early Urban Land Use Planning Regulations, 1900–1920*; Centre for Urban and Community Studies, University of Toronto: Toronto, ON, Canada, 1982; p. 39.
59. Sun, Y.; Song, K.; Feng, L. Planning Modern Cities in China: Urban Construction Regulations of Concessions in Tianjin (1860–1945). *Int. Plan. Hist. Soc. Proc.* **2018**, *18*, 1048–1059. [CrossRef]
60. Emamgholian, S.; Pouliot, J.; Shojaei, D. 3D Zoning: A Missing Piece to Link Planning Regulations with 3D Cadastre 3D Zoning: A Missing Piece to Link Planning Regulations with 3D Cadastre. In Proceedings of the 7th International FIG 3D Cadastre Workshop, New York, NY, USA, 11–13 October 2021; pp. 341–356.

61. UNEP. *Guidelines for Framework Legislation for Integrated Waste Management*; UNEP: Nairobi, Kenya, 2016.
62. Stoter, J.E.; de Kluijver, H.; Kurakula, V. 3D noise mapping in urban areas. *Int. J. Geogr. Inf. Sci.* **2008**, *22*, 907–924. [CrossRef]
63. Butler, D. Noise management: Sound and vision. *Nature* **2004**, *427*, 480–482. [CrossRef]
64. Law, C.W.; Lee, C.K.; Lui, A.S.W.; Yeung, M.K.L.; Lam, K.C. Advancement of Three-Dimensional Noise Mapping in Hong Kong. *Appl. Acoust.* **2011**, *72*, 534–543. [CrossRef]
65. Czerwinski, A.; Sandmann, S.; Stöcker-Meier, E.; Plümer, L. Sustainable SDI for EU noise mapping in NRW—Best practice for INSPIRE. *Int. J. Spat. Data Infrastruct. Res.* **2007**, *2*, 90–111.
66. Australian Radiation Protection and Nuclear Safety Agency (ARPANSA). *Radiation Protection Standard: Maximum Exposure Levels to Radiofrequency Fields—3 kHz to 300 GHz*; Chief Executive Officer of ARPANSA: Canberra, Australia, 2002.
67. Greater London Authority. London View Management Framework. 2012. Available online: https://www.london.gov.uk/priorities/planning/supplementary-planning-guidance/view-management (accessed on 18 November 2021).
68. Branco, J.P.; Meijer, F.; Visscher, H. Technical building regulations in EU countries: A comparison of their organization and formulation. In Proceedings of the W113-Special Track 18th CIB World Building Congress, Salford, UK, 10–13 May 2010; p. 12.
69. DEWLP. Planning Schemes 1. 2021. Available online: https://www.planning.vic.gov.au/__data/assets/pdf_file/0026/94535/1_Planning-Schemes.pdf (accessed on 15 November 2021).
70. International Code Council. *International Building Code 2012*; International Code Council: Washington, DC, USA, 2011.
71. Kitsakis, D.; Paasch, J.M.; Paulsson, J.; Navratil, G.; Vučić, N.; Karabin, M.; Tenorio Carneiro, F.; El-Mekawy, M. 3D Real Property Legal Concepts and Cadastre: A Comparative Study of Selected Countries to Propose a Way Forward. In *5th International FIG 3D Cadastre Workshop*; Van Oosterom, P., Dimopoulou, E., Fendel, E.M., Eds.; International Federation of Surveyors: Copenhagen, Denmark, 2016; pp. 1–24.
72. Grøv, E.; Lu, M. Design build large underground caverns the importance of understanding and utilizing in-situ rock stresses. In Proceedings of the Joint HKIE-HKIP Conference on Planning and Development of Underground Space, Hong Kong, China, 23–24 September 2011; pp. 19–35.
73. Takasaki, H.; Chikahisa, H.; Yuasa, Y. Planning and mapping of subsurface space in Japan. *Tunn. Undergr. Space Technol.* **2000**, *15*, 287–301. [CrossRef]
74. Vähäaho, I. Underground resources and master plan in Helsinki. In Proceedings of the 13th World Conference of the Associated Research Centers for the Urban Underground Space, Singapore, 7–9 November 2012; pp. 31–44. Available online: https://www.hel.fi/static/kv/Geo/CasePankki/0-LAND_USE.pdf (accessed on 1 December 2021).
75. Vähäaho, I. Underground space planning in Helsinki. *J. Rock Mech. Geotech. Eng.* **2014**, *6*, 387–398. [CrossRef]
76. Masuda, Y.; Takahashi, N.; Ojima, T. Utilization of Deep Underground Space in Tokyo -Urban Renewal with the City's New Backbone Lifeline. In Proceedings of the CTBUH 2004 Seoul Conference, Seoul, Korea, 10–13 October 2004.
77. Merrill, T.W.; Smith, H.E. What Happened to Property in Law and Economics? *Yale Law J.* **2001**, *111*, 357. [CrossRef]
78. Kaliampakos, D.; Benardos, A.; Mavrikos, A. A review on the economics of underground space utilization. *Tunn. Undergr. Space Technol.* **2016**, *55*, 236–244. [CrossRef]
79. Zaini, F.; Hussin, K.; Siti Radiation, A.Z. Legal and administrative issue for underground land development in Malaysia. In Proceedings of the 7th International Real Estate Research Symposium (IRERS 2014), Kuala Lumpur, Malaysia, 29–30 April 2014; p. 13.
80. Döner, F.; Thompson, R.; Stoter, J.; Lemmen, C.; Ploeger, H.; van Oosterom, P.; Zlatanova, S. 4D cadastres: First analysis of legal, organizational, and technical impact—With a case study on utility networks. *Land Use Policy* **2010**, *27*, 1068–1081. [CrossRef]
81. Döner, F.; Thompson, R.; Stoter, J.; Lemmen, C.; Ploeger, H.; van Oosterom, P.; Zlatanova, S. Solutions for 4D cadaster—With a case study on utility networks. *Int. J. Geogr. Inf. Sci.* **2011**, *25*, 1173–1189. [CrossRef]
82. Stoter, J.E. *3D Cadastre*; Delft University of Technology: Delft, The Netherlands, 2004.
83. Stoter, J.E.; Sørensen, E.M.; Bodum, L. 3D registration of real property in Denmark. In Proceedings of the FIG Working Week 2004, Athens, Greece, 22–27 May 2004; pp. 1–23. Available online: http://www.gdmc.nl/publications/2004/3D_registration_Denmark.pdf (accessed on 3 December 2021).
84. Kitsakis, D.; Dimopoulou, E. Addressing Public Law Restrictions within a 3D Cadastral Context. *ISPRS Int. J. Geo-Inf.* **2017**, *6*, 182. [CrossRef]
85. Tveiten, V.; Grepstad, G. Environmental management, monitoring and mitigation during construction. In *Health, Safety and Environment in Norwegian Tunnelling*; Norwegian Tunneling Society Helli—Visuell Kommunikasjon: Oslo, Norway, 2015; pp. 75–78.
86. Kitsakis, D.; Dimopoulou, E. 3D Cadastres: Legal Approaches and Necessary Reforms. *Surv. Rev.* **2014**, *46*, 322–332. [CrossRef]
87. Paasch, J.M. *Standardization of Real Property Rights and Public Regulations: The Legal Cadastral Domain Model*; KTH Royal Institute of Technology: Stockholm, Sweden, 2012.
88. Paasch, J.M.; Paulsson, J.; Navratil, G.; Vučić, N.; Kitsakis, D.; Karabin, M.; El-Mekawy, M. Building a Modern Cadastre: Legal Issues in Describing Real Property in 3D. *Geod. Vestn.* **2016**, *60*, 256–268. [CrossRef]
89. Paulsson, J. *3D Property Rights—An Analysis of Key Factors Based on International Experience*; KTH Royal Institute of Technology: Stockholm, Sweden, 2007.
90. International Organisation for Standardisation (ISO). *ISO 19152, Geographic Information—Land Administration Domain Model (LADM)*, 1st ed.; ISO: Geneva, Switzerland, 2012.

91. Kitsakis, D.; Kalogianni, E.; Dimopoulou, E.; van Oosterom, P.J.M. Requirements for Standardised Representation of Public Law Restrictions based on LADM. In Proceedings of the FIG Commission 3 Workshop and Annual Meeting—Spatial Information in the Era of Data Science: Challenges and Practical Solutions, Naples, Italy, 3–6 December 2018.
92. Kitsakis, D.; Kalogianni, E.; Dimopoulou, E.; Zevenbergen, J.; van Oosterom, P. Modelling 3D legal spaces of Public Law Restrictions within the context of LADM revision. In Proceedings of the 7th International FIG 3D Cadastre Workshop, New York, NY, USA, 11–13 October 2021. [CrossRef]
93. Paasch, J.M.; van Oosterom, P.J.M.; Lemmen, C.; Paulsson, J. Further modelling of LADM's rights, restrictions and responsibilities (RRRs). *Land Use Policy* **2015**, *49*, 680–689. [CrossRef]
94. Atazadeh, B.; Rajabifard, A.; Kalantari, M. Connecting LADM and IFC Standards—Pathways towards an Integrated Legal-Physical Model. In Proceedings of the 7th International FIG Workshop on the Land Administration Domain Model, Zagreb, Croatia, 12–13 April 2018.
95. Kalogianni, E.; Dimopoulou, E.; Lemmen, C.; van Oosterom, P. BIM/IFC files for 3D real property registration: An initial analysis. In Proceedings of the FIG Working Week 2020: Smart Surveyors for Land and Water Management, Amsterdam, The Netherlands, 10–14 May 2020.
96. Alattas, A.F.M.; Kalogianni, E.; Alzahrani, T.; Zlatanova, S.; van Oosterom, P.J.M. Mapping private, common, and exclusive common spaces in buildings from BIM/IFC to LADM: A case study from Saudi Arabia. *Land Use Policy* **2021**, *104*, 105355. [CrossRef]
97. Ramlakhan, R.; Kalogianni, E.; van Oosterom, P.J.M. Modelling 3D underground legal spaces in 3D Land Administration Systems. In Proceedings of the 7th International FIG 3D Cadastre Workshop, New York, NY, USA, 11–13 October 2021. [CrossRef]
98. OGC. OGC LandInfra/InfraGML. 2021. Available online: https://www.ogc.org/standards/infragml (accessed on 1 December 2021).
99. Dolan, A.M.; Thompson, R.M.I. *Integration of Drones into Domestic Airspace: Selected Legal Issues*; Congressional Research Service: Washington, DC, USA, 2013.
100. Cahoon, C. Low Altitude Airspace: A Property Rights No-Man's Land. *J. Air Law Commer.* **1990**, *56*, 157–198.
101. Widener, M. Local regulating of drone activity in lower airspace. *Boston Univ. J. Sci. Technol. Law* **2016**, *22*, 239. [CrossRef]
102. Edelenbos, J.; Monnikhof, R.; Haasnoot, J.; van der Hoeven, F.; Horvat, E.; van der Krogt, R. Strategic study on the utilization of underground space in The Netherlands. *Tunn. Undergr. Space Technol.* **1998**, *13*, 159–165. [CrossRef]
103. Groetelaers, D.A.; Ploeger, H. Juritecture of the built environment: A different view on legal design for multiple use of land. *Struct. Surv.* **2007**, *25*, 293–305. [CrossRef]
104. Emmi, P.C. Urban Complexity and Spatial Strategies: Towards a Relational Planning for Our Times. *J. Am. Plan. Assoc.* **2008**, *74*, 137. [CrossRef]
105. Admiraal, H.; Cornaro, A. Why underground space should be included in urban planning policy—And how this will enhance an urban underground future. *Tunn. Undergr. Space Technol.* **2016**, *55*, 214–220. [CrossRef]
106. Zhao, J.W.; Peng, F.L.; Wang, T.Q.; Zhang, X.Y.; Jiang, B.N. Advances in master planning of urban underground space (UUS) in China. *Tunn. Undergr. Space Technol.* **2016**, *55*, 290–307. [CrossRef]
107. Kishii, T. Utilization of underground space in Japan. *Tunn. Undergr. Space Technol.* **2016**, *55*, 320–323. [CrossRef]
108. Belyaev, V. Underground Development as Part of the Strategy for Sustainable Spatial Development of the City of Moscow. *Procedia Eng.* **2016**, *165*, 277–281. [CrossRef]
109. Bartel, S.; Janssen, G. Underground spatial planning—Perspectives and current research in Germany. *Tunn. Undergr. Space Technol.* **2016**, *55*, 112–117. [CrossRef]
110. Nolde, M.; Schwanebeck, M.; Dethlefsen, F.; Duttmann, R.; Dahmke, A. Utilization of a 3D webGIS to support spatial planning regarding underground energy storage in the context of the German energy system transition at the example of the federal state of Schleswig–Holstein. *Environ. Earth Sci.* **2016**, *75*, 1284. [CrossRef]
111. Danese, M.; Las Casas, G.; Murgante, B. 3D Simulations in Environmental Impact Assessment. In *International Conference on Computational Science and Its Applications—ICCSA 2008*; Springer: Berlin/Heidelberg, Germany, 2008; Volume 5072, pp. 430–443. [CrossRef]
112. Hełdak, M.; Szczepański, J.; Patrzałek, C. Using the 3D Computer Scanning Method in the Environmental Impact Assessment. *Infrastruct. Ecol. Rural Areas* **2012**, *1/IV*, 49–59.
113. Ngo, L.K.K.; Tsand, T.S.W.; Wong, C.Y.K. 3-dimensional EIA—A Greener Tool to Plan and Design. In Proceedings of the IAIA14 Conference Proceedings, Viña del Mar, Chile, 8–11 April 2014; pp. 1–6.
114. Loh, E.; Dawood, N.; Dean, J. Integration of 3D tool with Environmental Impact Assessment (3D EIA). In Proceedings of the 3rd International ASCAAD Conference on Embodying Virtual Architecture, Alexandria, Egypt, 28–30 November 2007.
115. Del Campo, A.G. Gis in Environmental Assessment: A Review of Current Issues and Future Needs. *J. Environ. Assess. Policy Manag.* **2012**, *14*, 1250007. [CrossRef]
116. Lai, P.C.; Kwong, K.H.; Mak, A.S.H. Assessing the applicability and effectiveness of 3D visualisation in environmental impact assessment. *Environ. Plan. B Plan. Des.* **2010**, *37*, 221–233. [CrossRef]
117. Çoruhlu, Y.E.; Demir, O.; Yıldız, O.; Çete, M. The relation between structured cultural heritages and condominium towards 3D cadastre. *Surv. Rev.* **2016**, *48*, 438–449. [CrossRef]

118. Vucic, N. The Role of 3D Cadastre in the Preservation of Historical Cultural Heritage. In *Contributions to International Conferences on Engineering Surveying*; Kopáčik, A., Kyrinovič, P., Erdélyi, J., Paar, R., Marendić, A., Eds.; Springer: Cham, Switzerland, 2021. [CrossRef]
119. Stoter, J.E.; Ho, S.; Biljecki, F. Considerations for a contemporary 3D cadastre for our times. *Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci.* **2019**, *42*, 81–88. [CrossRef]
120. Kaufmann, J.; Steudler, D. Cadastre 2014: A Vision for a Future Cadastral System. 1998. Available online: https://www.fig.net/resources/publications/figpub/cadastre2014/translation/c2014-english.pdf (accessed on 15 November 2021).
121. Zevenbergen, J.; De Jong, J. Public Law Information Regarding Land: Dutch proposal for registration. In Proceedings of the FIG XXII International Congress, Washington, DC, USA, 19–26 April 2002; pp. 1–11.
122. Frank, A.U.; Fuhrmann, T.; Navratil, G. Extending 3D city models with legal information. In Proceedings of the Usage, Usability, and Utility of 3D City Models—European COST Action TU0801, Nantes, France, 29–31 October 2012; p. 8.
123. Besse, M. The Cadastre of Public-Law Restrictions on Landownership (PLR Cadastre) in Switzerland. In Proceedings of the FIG e-Working Week 2021, Apeldoorn, The Netherlands, 21 June 2021.
124. Steudler, D. 10 Years of "Law on Geoinformation "in Switzerland. In Proceedings of the FIG Working Week 2019, Hanoi, Vietnam, 22–26 April 2019.
125. Federal Office of Topography Swisstopo. (2021). Further Development of the PLR Cadastre. Retrieved December 7, 2021. Available online: https://www.cadastre.ch/en/oereb/planning (accessed on 5 December 2021).
126. Federal Office of Topography Swisstopo. The Cadastre of Public-law Restrictions on Landownership (PLR-Cadastre). Available online: https://www.cadastre.ch/en/services/publication.detail.publication.html/cadastre-internet/en/publications/Broschuere-OEREB-Kataster-en.pdf.html (accessed on 5 December 2021).
127. Vandysheva, N.; Ivanov, A.; Pakhomov, S.; Spiering, B.; Stoter, J.; Zlatanova, S.; Van Oosterom, P. Design of the 3D Cadastre Model and Development of the Prototype in the Russian Federation. In Proceedings of the 2nd International Workshop on 3D Cadastres, Delft, The Netherlands, 16–18 November 2011.
128. Cayla, N.; Martin, S. Digital Geovisualisation Technologies Applied to Geoheritage Management. In *Geoheritage*; Reynard, E., Ed.; Elsevier Inc.: Amsterdam, The Netherlands, 2018; pp. 289–303. [CrossRef]
129. Ducci, D.; Sellerino, M. Vulnerability mapping of groundwater contamination based on 3D lithostratigraphical models of porous aquifers. *Sci. Total Environ.* **2013**, *447*, 315–322. [CrossRef] [PubMed]
130. Sheng, N. *Prediction and 3D Visualization of Environmental Indicators: Noise and Air Pollution*; Royal Institute of Technology (KTH): Stockholm, Sweden, 2011.