Determining the “true” three-dimensional environmental impact of Public Law Restrictions

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Key words: PLR, 3D Cadastre, environmental impact, legal framework

SUMMARY

The needs of modern, heavily urbanised societies, require, on the one hand, the most efficient exploitation of land by individual stakeholders and, on the other hand, have set up a variety of restrictions and regulations for the public benefit. Such restrictions are steadily growing in number and apply in various areas. Given the technological development in the construction sector, complex proprietary relations emerge in overlapping private and public rights. Cadastres constitute the core of land administration systems, gradually evolving to development tools that provide multi-purpose land related information. Within this context, incorporation of Public Law Restrictions (PLRs) to cadastral systems is considered a step towards the development of integrated cadastral systems. Internationally, PLRs are registered in separate registries, using different types and formats, depending on the competent body. They include, among others, restrictions regarding environment and nature protection, water protection, spatial and land use planning zones, cultural heritage, public infrastructure corridors and zones, public easements/servitudes and mining rights. Until today 3D registration and visualisation of such PLRs is mostly discussed at research level, mainly due to the variety of scientific fields related to each PLR, the need of quantifying qualitative components or “translating” physical attributes to legal restrictions and 3D volumes, as well as to the variety of responsible authorities and types of regulations. This paper focuses on identifying PLRs that pertain either explicit or implicit 3D characteristics, emphasising on the PLRs related to the development of the Trans Adriatic Pipeline (TAP) project. To this purpose, the Environmental and Social Impact Assessment (ESIA) for the Greek section of the pipeline has been used as input, to identify the 3D PLRs that affect the pipeline’s installation, as well as their impact on the rights of affected parcels. Based on the constraints and legal requirements provided by the ESIA report, this paper considers broader PLRs’ legislation issues at a national and international level, concerning environmental protection that is: soil and groundwater, protected areas, landscape protection, restrictions on private land parcels crossed by the pipeline, or intersection with other underground infrastructures. This paper continues the authors’ research on issues linking 3D Cadastre to Public Law. The outcomes of this research can be used to identify and classify the complexities of transforming qualitative features into spatial dimensions, thus contributing to the 3D modelling of overlapping legal spaces related to various Public Law restrictions.

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1. INTRODUCTION

Following the structure of traditional cadastral systems, 3D Cadastre research emphasises on stratified real property rights and restrictions that apply, primarily, to residential buildings and, secondarily, to infrastructures, based on Private Law. Although this approach covers a great portion of Land Administration requirements, it does not exploit the capabilities of 3D Cadastre in full. Specifically, the domain of statutory imposed regulations (or restrictions) on land, known as Public Law Restrictions (PLRs) are usually ignored. However, PLRs affect land management to a significant extent as their number is growing rapidly, while legislation assigns them vertical characteristics, either directly, or implicitly in terms of non-geometrical, physical characteristics (Kitsakis and Papageorgaki, 2017). The 3D nature of PLRs, along with their range of applications have been discussed by several researchers in literature. Navratil (2012), discusses the consequences of PLRs on 3D cadastral context, while Kitsakis and Dimopoulou (2016) identify the range of existing 3D PLRs, also presenting characteristic cases of 3D PLRs within Greek law. This work was further expanded by a case study that presents the interrelation between 3D PLRs for the development of major infrastructures (Kitsakis and Dimopoulou, 2017). The relation of 3D PLRs with environmental protection, especially groundwater protection, is discussed by Kitsakis and Papageorgaki (2017).
Environmental protection has attained national and international attention, being constitutionally protected, while, along with sustainability, is among the development goals set by the United Nations (UN, 2015). Physical environment constitutes a complex system of interrelated components such as soil, surface and groundwater, fauna, flora and landscape that cannot always be quantified, while not all relations between such components can be defined. Therefore, environmental protection legislation usually creates a dense, complex fabric of regulations, based on specific cases. Environmental protection constitutes one of the main fields of state interventionism, imposing various types of restrictions and responsibilities on land (Siouti, 2011). Development of major infrastructure projects implies significant changes on natural environment and entails environmental risks. To mitigate such risks and compromise environment protection and economic growth, environmental restrictions are imposed either directly defined in 3D, by reference to height, depth, volume, or implied, e.g. groundwater protection depends on the above-lying soil characteristics. Exploitation of 3D models in case of infrastructures has been proposed by several researchers, e.g. Doner et al. (2010), Vandysheva et al. (2011), as well as in environmental applications and in Environmental Impact Assessment studies (Stoter et al., 2008; Danese et al., 2008; Kurakula, 2007; Sheng, 2011; Heldak et al, 2012; Ducci and Sellerino, 2013), fostering public participation and flexibility in planning options (Lai et al., 2010). However, technical limitations such as level of detail, cost, system architecture requirements, as well as data accuracy, scale consistency and completeness need to be addressed, so that results' reliability and accountability is ensured (Lai et al., 2010; Gonzáles, 2012). On the other hand, each country has established several registries recording PLRs. Number and type of registered

PLRs differ, but environmental ones are the most common PLRs registered (CLRKEN, 2015). In general, no centralised PLR registries are established; each country uses thematic registries, such as archaeological cadastres, utility cadastres or environmental cadastres, where 2D spatial data is recorded for each type of object. In Switzerland, the need of a centralised registry maintaining all PLRs imposed on land has resulted to the establishment of cantonal PLR cadastres. Swiss PLR cadastres register 17 PLRs (10 of federal and 7 of cantonal law), classified in 8 sectors (Federal Office of Topography, 2015). Despite its innovation, Swiss PLR cadastre is 2D based, using 2D polygons on 2D maps. However, interest is shown in transition of Swiss PLR cadastre to 3D, e.g. Givord (2012).
In this paper, PLRs with environmental impact are examined, to identify those explicitly or implicitly pertaining 3D characteristics. The research specifies to the Environmental and Social Impact Assessment study of the Trans Adriatic Pipeline (TAP) project that is under development in Northern Greece.

2. ASSESSING ENVIRONMENTAL IMPACT

Environmental Impact Assessment (EIA) is an instrument that is used to evaluate possible impacts of a development to the environment. EIA is an iterative process that aims to identify potential negative environmental impacts deriving from a development project and minimise their effect, to achieve sustainable development. EIA was first introduced by the United States National Environment Policy Act (NEPA) in 1969 (Caldwell, 1988) and in the environmental laws of several countries in the following decades (Glasson et al., 1999). Standards of EIA are based on environmental performance and quality requirements and are defined by national and international legal instruments. Several environmental and social aspects are expressed in qualitative terms, therefore appropriate significance criteria were developed (ESIA, 2013).
Currently, EIAs are strongly related to GIS systems to perform interpretation and analysis of collected data, as well as to present relevant information on maps and charts. They also present the significance of residual impacts after mitigation measures using checklists, matrices, networks, overlays and geographic information systems (GIS), expert systems and professional judgement (UNEP, 2002) (examples are presented in Fig. 1). Significance is strongly dependent on each specific project. Therefore, no uniform significance criteria can be defined; significance criteria are based on the characteristics of each type of impact and on the values of the environmental issues affected (European Commission, 2017). Use of 3D modelling in EIAs is limited to the creation of photomontages in case of landscape analysis, combined with GIS methods. Potential contribution of 3D modelling techniques in impact assessment is presented in several research works (Danese et al., 2008; Heldak et al., 2012; Ngo et al., 2014). However, concerns regarding technical requirements and data suitability are also raised (Lai et al., 2010; González, 2012).

3. CASE STUDY

3.1 Trans Adriatic Pipeline (TAP)

TAP is a pipeline that is developed to carry natural gas from the Caspian region to South Eastern and Western Europe. The pipeline's capacity is designed to be of 10 billion cubic meters per year (bcm/year), expandable to 20 bcm/year (ESIA, 2012). Total pipeline's length is estimated to 860 km, distributed in Greece (546 km), Albania (204 km), the offshore Adriatic Sea (105 km) and Italy (5 km). The pipeline will be buried at least one meter below the earth's surface, while its elevation ranges from 1800 meters height (highest elevation point), to 810 meters depth (lowest offshore point) (ESIA, 2012).

The Greek section of TAP is further divided in two subsections. The East Section covers approximately 365 km in length, starting from the Greek-Turkish border, where TAP is connected to the Trans Anatolian Pipeline (TANAP), and crosses the regions of Thrace, Eastern and Central Macedonia, while the West Section, of approximately 181 km, runs the region of Western Macedonia to reach the Greek-Albanian border.

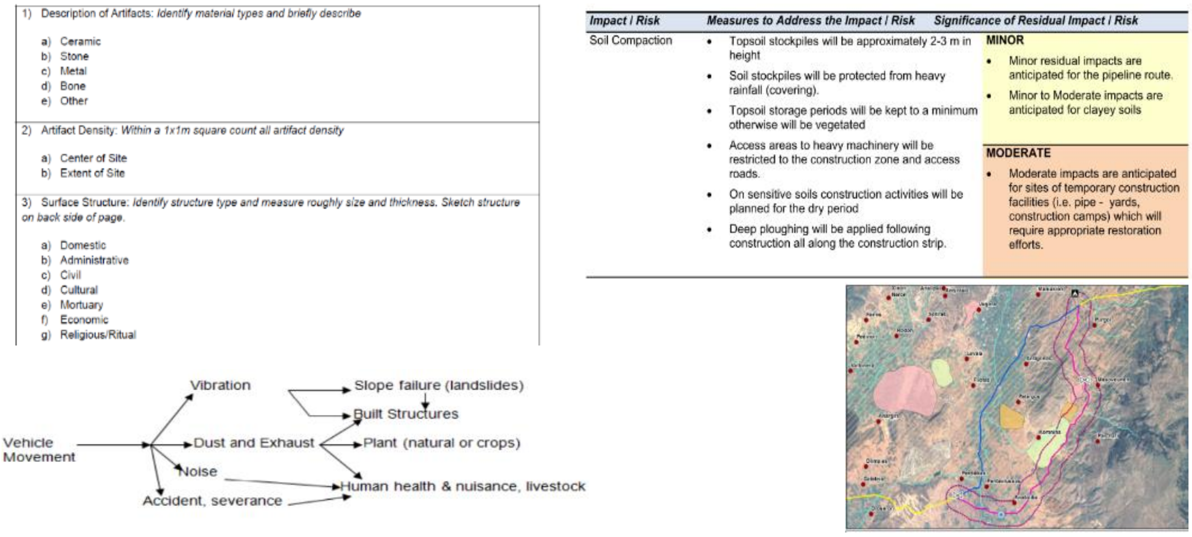

Figure 1: (*Top left*) Site observation checklist (ESIA, 2013), (*Top right*) Residual Impacts – Subsurface and Soil - Construction Phase (ESIA, 2013), (*Bottom left*) Effects of vehicular movement during developmental activity (https://eco-intelligent.com) (*Bottom right*) Rerouting in relation to PPC concession area, active/planned mines and known lignite deposits (ESIA, 2013)

3.2 Methodology

To achieve this paper's aim, the Environmental and Social Impact Assessment of TAP is examined, in order to determine the 3D impact of PLRs described in the report, in relation to the provisions in force. First, baseline conditions within the pipeline's corridor are examined, based on the Baseline Studies and Baseline Supporting Studies of ESIA. This aims to identify the background conditions of the area and the local physical, biological and socioeconomic characteristics with direct or implied 3D components. In the next step, Public Law regulations or restrictions which apply to 3D space were identified, based on the ESIA documents. Assessment of Impact and Mitigation Measures, Appropriate Assessment and Management Plans are among the documentation used during this stage of the research. Justification of the 3D aspects of the identified PLRs and possibilities of further exploitation of 3D PLRs are also presented in this step. Then, characteristic cases of 3D PLRs are visualised (ESRI CityEngine software), justifying the benefits of 3D modelling of PLRs, compared to current environmental impact assessment methods.

4. BASELINE CONDITIONS AND RESTRICTIONS

This section presents the baseline conditions that apply to the study area. Baseline conditions are classified in the following categories (ESIA, 2013):

- *Physical Environment* This category includes geology and soils, land, hydrology, surface and ground water resources, air and noise.
- *Biological Environment* Biological environment includes aquatic and terrestrial habitats, flora and fauna, biodiversity and protected areas.
- *Socioeconomic Environment* Within socioeconomic environment a variety of characteristics are included such as land use, demography, employment, education, infrastructure, public services and public health.
- *Cultural Heritage* Cultural heritage pertains designated and potential archaeological sites, monuments and intangible cultural heritage.

It needs to be noted that each category can be further sub-classified, depending on the extent of the topic examined. For example, fauna baseline is further classified based on the species that reside within the pipeline's route or its greater area, such as bear, wolf, jackal, souslik (European ground squirrel) and herpetofauna.

4.1 Physical Environment

The following subsections briefly present characteristic examples of physical environment features that have a 3D impact on the pipeline's installation, operation and maintenance phases, and can also be used to define 3D PLRs. No elaboration or exhaustive analysis of such features is intended.

4.1.1 Geology

Geological characteristics examined by the ESIA include lithostratigraphy and geohazards. Lithostratigraphy provides the geological background of the area to understand geometry and tectonism of geological strata (ESIA, 2013). Lithological logs depict the occurrence of subsurface materials, whose characteristics, e.g. porosity, can be used to define soil or groundwater vulnerability volumes.

3D-based geohazards include soil liquefaction and karst areas. Volumes of sandy materials, susceptible to liquefaction, can be defined along with depth regulations to increase their strength and density (such as lowering of groundwater tables, or depth restrictions to circumvent liquefiable soils). In karst areas, volumes where the pipeline is susceptible to deformation, spanning or rupture, or volumes vulnerable to soil and groundwater contamination due to the voids and caves within karst formations can be defined.

4.1.2 Subsurface and soils

Soil properties, combined with topographical characteristics, imply risks of erosion and compaction. Additionally, soil characteristics affect the vulnerability of groundwater to pollution, as well as the depth of soil pollution. For example, Greek soils are characterised by higher nitrate contamination in depth ranging from the land surface to 30 cm below, while lower levels of pollution are presented in depth from 30 cm to 70 cm below the land surface (also depending on the type of cultivated crops). Such data can be used to define 3D soil or groundwater vulnerability spaces that can be further combined either with other 3D PLRs, or for environmental assessment and decision making.

4.1.3 Groundwater

Parameters of 3D characteristics that impact on groundwater quality include groundwater table's depth and the permeability both of the aquifer and of its overlying strata. Differentiation of soil characteristics, even within the area of the same aquifer, do not allow unique vulnerability classification of groundwater (ESIA, 2013). Most commonly, groundwater vulnerability maps are used as reference to define the vulnerability of the studied area (in case of TAP no vulnerability maps for Greece were available), based on 2D GIS tools. Hydrogeological setting of groundwater bodies is literally described in ESIA (e.g. Annex 6.6.2), including reference to aquifers' type (shallow, confined, unconfined), depth and 2D groundwater body maps.

4.1.4 Ambient air quality

Air includes all invisible gaseous substances around the earth. Air quality is defined through measuring the concentration of pollutants within a specific volume of air. Combined with climate and wind characteristics, pollutants can be propagated in 3D space. Despite its undisputed 3D nature, air quality is presented in 2D. Similarly applies to ESIA analysis on ambient air quality (ESIA, 2013). Regardless the fact that 3D representation of air quality would improve presentation and understanding, it would be required only in cases where interaction among different phenomena is required, such as air pollution within bird migration routes.

4.1.5 Acoustic Environment

Similarly to air, noise also is of 3D nature. Noise is propagated in 3D and noise levels differ at different height levels. 3D noise representation is already used in case of urban environment with high-rise buildings, e.g. Kurakula (2007). In case of TAP project, 2D maps along with diagrams of sound pressure level are used to define the level of noise in the vicinity of the pipeline's development area and permanent facilities.

4.1.6 Landscape Quality

ESIA Baseline Study on Landscape (Annex 6.6.4) defines landscape character as the distinct and recognisable pattern of elements that occurs consistently in a particular type of landscape, and how this is perceived by people. Depending on the level of importance of landscape that derives from its quality and special features, value is assigned to landscape, while changes, e.g. construction of a development, within a landscape are evaluated based on the sensitivity of the landscape character to be affected by such changes (ESIA, 2013). In case of TAP, construction activities impact landscape unity not only during construction phase, but during operation and maintenance phase as well, due to the restrictions applying to the permanent pipeline protection strip (PPS). Landscape quality is assessed using a 10 kilometre wide zone around the pipeline (5 kilometres from the pipeline's centreline). Landscape and visual analysis in the ESIA (Annex 6.6.4), provides for the use of 2D and 3D data, e.g. topographic maps, protected areas, cultural heritage areas, Digital Terrain Model (DTM), existing infrastructure and digital photographs acquired during field survey. Such data were used for the description of landscape character, landscape quality assessment and to create 3D simulations including view shed analyses and 3D model and photomontages.

4.2 Biological environment

Biological environment components that can be described in 3D or that can be affected by 3D PLRs are briefly presented in this section.

4.2.1 Flora

A great variety of flora species and subspecies can be traced along TAP pipeline's route, especially along the 500-metre corridor from pipeline's centreline, many of which are protected under Greek or European Union legislation (ESIA 2013). 3D component of flora protection-related PLRs has to do, on the one hand, with flora species that grow within specific altitudes, and, on the other hand, with restrictions on soil or groundwater pollution in the vicinity of protected flora. Restrictions on the PPS after pipeline's installation also affects flora, especially deep root trees and are also related to PLRs that apply to landscape protection.

4.2.2 Fauna

Fauna includes species of mammals, birds, amphibians and reptiles and aquatic ecology. ESIA (2013) identifies several species of conservation interest, both by national and European Union legislation. 3D component of fauna habitats derives either from specific altitude or depth within which particular species reside (combined with already implied habitat modelling techniques), or from soil and groundwater protection in the vicinity of fauna habitats.

4.2.3 Protected areas, sites of conservation interest

Protected areas are characterised by high ecological and biological value and may comprise habitats of rare, threatened or endangered fauna and flora. Protected sites combine natural habitats, species of flora, fauna and birds. Sites of conservation interest share similar physical characteristics with protected sites, although are not statutorily protected, such as CORINE biotopes (ESIA, 2013). 3D-defined baseline conditions may refer to specific altitudes where species reside or grow, soil and groundwater protection and landscape conditions.

4.3 Socioeconomic Environment

Socioeconomic environment covers a great variety of fields. Of interest to set 3D baseline conditions and to be used within a 3D PLR context are those of land tenure and use, along with infrastructure and public services. The latter include all roads, harbours, airports, railways, as well as all types of networks such as water and sanitation, irrigation, waste management, energy and telecommunications (ESIA, 2013). Most of these networks are developed above or below the earth's surface and their operation and maintenance implies specific regulations, regarding access, security, potential overlaps with other infrastructures, protection or other, 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. Location of utility networks, zones influenced by utilities, e.g. protection zones around cables or polluted soils or groundwater zones, constitute 3D socioeconomic baseline data that can be used to estimate 3D overlaps and bypass possible defects in project design and development.

4.4 Cultural Heritage

The route of TAP passes along the regions of Thrace and Macedonia in Northern Greece, which are characterised by their rich history and culture, with archaeological findings from the Palaeolithic (250000 B.C), to the modern period (late 19^{th} century to present) (ESIA, 2013). ESIA baseline (Annex 4.7) classifies cultural heritage sites to the following types:

- *Archaeological sites*: areas of ancient or historic human activity, or occupation, often including subsurface resources and which can at times be identified by the presence of surface artefacts or structural remains.
- *Monuments*: above ground structures of public interest and/ or historical significance.
- *Sites of Intangible Cultural Heritage value (ICH)*: sites that reflect the spiritual or cultural lives of modern populations.

Cultural heritage sites are defined by their location in 2D, while legal restrictions are imposed on the affected land parcels as a whole. Special protection zones may be established in the area surrounding cultural heritage sites, where restrictions or other regulations apply. Maps presenting the 2D location of cultural heritage features have been prepared by the ESIA (Annex 4.7). Reference on areas of high archaeological potential, identified during route survey, are also presented in such 2D maps. However, no reference is made on the vertical dimension of such areas; restrictions that apply can only be traced by reference to corresponding legal documents.

4.5 Restrictions

This subsection presents the restrictions that are imposed on real property that is crossed by the pipeline. Restrictions are based on Section 8 of ESIA Greece (2013), on the assessment of impacts and mitigation measures.

4.5.1 Soils

In order to prevent impact on soil and subsurface the following mitigation measures with 3D characteristics have been adopted (ESIA, 2013):

- Use of special granular backfill/bedding material in combination with oversized trenches to hinder the impact of fault movements on ground surface (Fig. 2 left).
- Increase density and strength of sandy materials, by lowering the groundwater table or replacement of liquefiable soils, can be employed to prevent soil liquefaction. Such measures either have a direct 3D counterpart, e.g. volumes of materials whose density and strength require to be increased, regulations on groundwater table height, or are related to physical characteristics that impact on 3D space (e.g. soils of low density and strength create volumes susceptible to liquefaction) (Fig. 2, right).
- To prevent potential liquefaction in areas of river crossings, trenchless crossings crossing below liquefiable soil deposits can be employed (Fig. 2, right).
- Reduction of slope inclinations with additional soil deposits, lowering groundwater levels, replacing or reinforcing sensitive soil layers to mitigate landslide risk.
- In the vicinity of contaminated areas, the pipeline trench will be either lined with impermeable materials or will be backfilled with low permeability materials (Fig. 2 left).
- Use of agricultural soil to a ploughing depth up to 30 cm and prohibition of deep routing vegetation within the pipeline protection strip.

4.5.2 Groundwater

Mitigation measures to prevent impact on water resources, related to 3D characteristics are the following (ESIA, 2013):

- In case of watercourse crossings, specifications for minimising sediment dispersion and impacts on river ecology are required. Depending on the means of minimising sediment dispersion, volumes of containment of sediment disposal can be created allowing the management of sediments.
- Management of groundwater pumping and surface run-off (ESIA, 2013). This relates to measures of mitigating disturbance of irrigation system, while it is also associated with physical characteristics such as soil type, elevation and topography, which prevent or delay runoff from continuing downstream (USGS, 2018).
- Measures to intercept run-off from the working corridor. Employed measures, e.g. sandbags or settlement tanks, define the volumetric capacity of water run-off that can be intersected from the working corridor.
- Employment of cut-off ditches to prevent water from entering to excavations. Cut-off ditches may prevent specific water capacities based on their depth and soil characteristics, thus creating 3D volumetric protection zones around the area of excavations.
- Use of bunded areas to store materials with polluting potential. Bunded areas need to be, at least, of 110% capacity of the largest storage tank plus 10% of the aggregate volume of all storage tanks. Hazardous substances require to be stored within impermeable bunded areas to prevent groundwater pollution by accidental spills. Ground surface in areas of vulnerable groundwater resources needs to be upgraded to impermeable for use at temporary facilities, so that accidental groundwater pollution is prevented. Above mentioned measures are either directly defined in 3D, e.g. by reference to storage volume, or in relation to ground characteristics, e.g. permeability level.
- Due to the depth of drainage networks' constructions (0.7-0.9 metres), trenching of drainage networks in the crossing area needs to be carried out by non-mechanical means. Although this does not imply a limitation applying to 3D space, it could be used to define 3D zones either for the protection of the pipeline or prohibiting mechanical excavation below a specific depth (Fig. 3, left).
- Identification of the volume of water that can be extracted from a water source, especially in aquifers near the sea, to avoid sea water intrusion (Fig. 3, right).

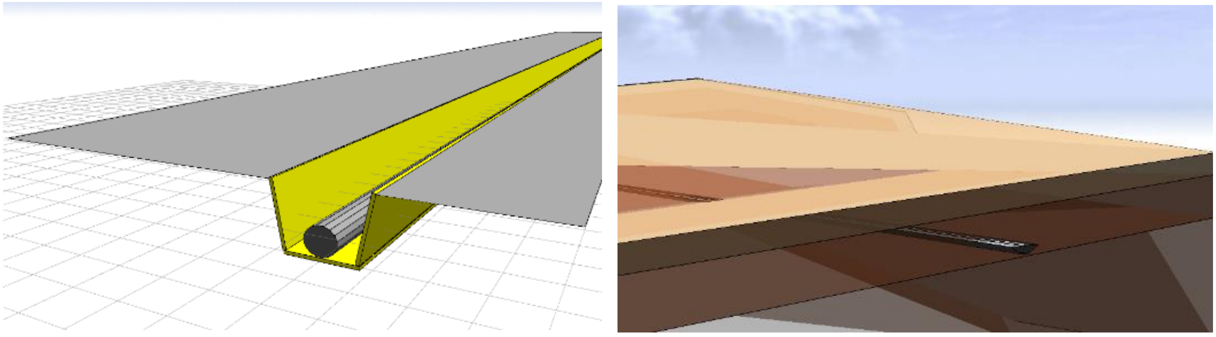

Figure 2. Left: Pipeline working strip and trench backfill (in yellow). Right: Volume of liquefiable soil (light brown) and volume of non-susceptible to liquefaction soil (dark brown)

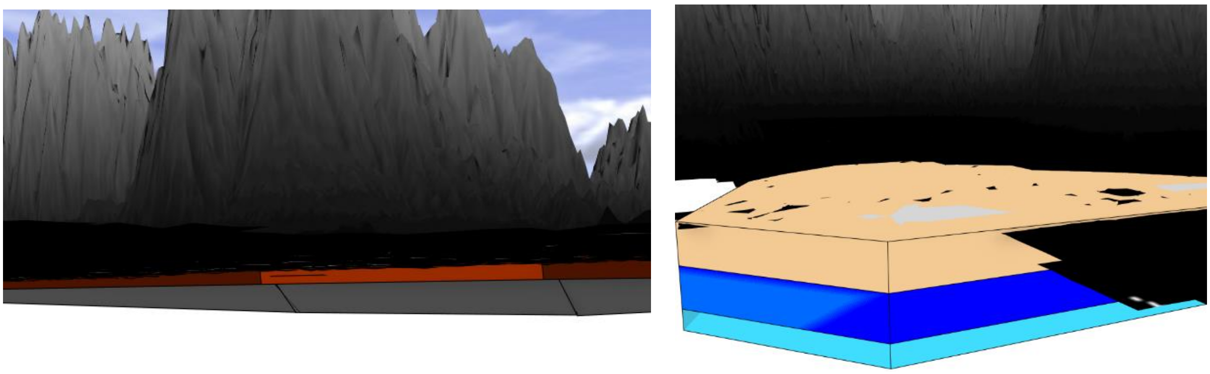

Figure 3. Left: Irrigation restrictions' zone (orange) above pipeline's trench. Right: Stratification of freshwater (deep blue) and sea water (light blue) in aquifers near the sea

4.5.3 Biological environment

Terrestrial Ecology

Terrestrial ecology includes habitats, fauna and flora within the pipeline's route. The main sources of impact from the pipeline's development derive from the movement of vehicles, equipment and personnel, the preparation of the working strip and the installation of the pipeline procedures, river crossings, as well as the maintenance of the pipeline's protection strip (ESIA, 2013).

Terrestrial ecology protection involves a significant number of mitigation measures, addressing habitat loss, habitat fragmentation, disturbance or displacement of fauna species, and species' population loss. Mitigation measures with 3D connotation are the following:

- Establishment of working strip to restrict area of impact within working corridor. This creates a spatial volume within which construction processes require to be held and can be further associated with other types of subsurface PLRs.
- Conducting of pre-construction survey to identify *Spermophylus citellus* colonies, potential colony sites, especially in the vicinity of already identified colonies. Given that this type of species resides up to 2 metres below the ground, a volume of this species residence can be delineated, to adopt temporary displacement measures (Fig. 4, right).

It needs to be noted that further mitigation measures for the protection of fauna can be defined in Biodiversity Action Plans.

Freshwater ecology

Pipeline's route is estimated to cross more than 820 watercourses of varying types, including large rivers, channels, creeks, streamlets and ditches (ESIA, 2013).

Mitigation measures regarding freshwater ecology that involve 3D characteristics are the following (ESIA, 2013):

- Use of reduced or minimal working strip where riparian forest/sensitive habitats are traced.
- Site restoration upon completion of constructions, especially on the river banks so that risks of erosion and sediment entrainment in the aquatic environment are minimised.
- Silt screens must be constructed on both banks of the watercourse to retain, settle and filter any run off water.
- Measures to prevent erosion and flooding.

Protected areas

TAP pipeline crosses 7 "Natura 2000" regions, within which Important Bird Areas are enclosed, as well as 2 National Parks and 8 Wildlife Refuge Areas. In several cases, regions of different protected areas are overlapping. The area of protected sites crossed by the pipeline ranges from 300 metres to 42.5 kilometres (ESIA, 2013).

Seven "Natura 2000" sites were identified to be potentially affected by the development of the pipeline, and corresponding Appropriate Assessment documents were compiled, elaborating the impacts and the required mitigation measures (ESIA, 2013). Mitigation measures of 3D connotation include:

- Identification of important sites for species (for example breeding, feeding, nesting sites). These sites need to be avoided throughout the construction period.
- Creation of a buffer to visual/light/noise sources around work area in sites where species of conservation interest have been verified, at distance less than 500 m, by using screens.
- Temporary or permanent provisions for fauna to cross the working strip/roads using underpasses, tunnels or other measures (Fig. 4, left).
- Where ponds are located, efforts to avoid them are required. In case that ponds cannot be retained, any sensitive amphibians present need to be removed, including provision for an alternative pond to put in translocated species.
- Litter and other waste material have to be stored and disposed of appropriately in order to minimize a potential risk of damaging or polluting habitats and species. This involves soil characteristics, such as permeability, and volume capacity.

Mitigation measures for the protection of National Parks and Wildlife Refuge Areas are very close to those referring to the protection of terrestrial and freshwater ecology with area-specific modifications.

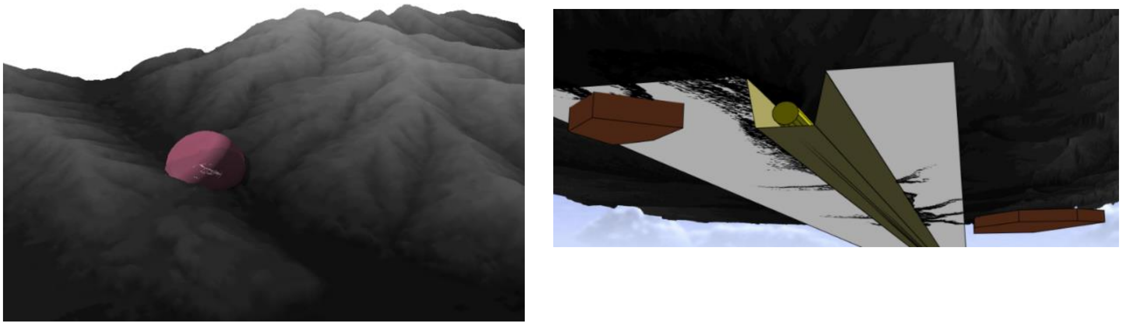

Figure 4. Left: Buffer to visual/light/sound sources. Right: Bottom view of the pipeline and European ground squirrel habitats (brown) on DTM

4.5.4 Cultural heritage

According to the ESIA (2013), 24 cultural heritage sites have been identified along the case study area, corresponding to almost all historical periods. Out of these sites, 16 have been characterised as associated areas of high archaeological potential[1], while 11 of them are characterised of high importance and/or quality (ESIA, 2013). Unknown subsurface archaeological resources and potential need of Chance Find Procedures pose further risks or impact on project's development.

Mitigation measures stipulated in order to protect cultural heritage sites implying 3D characteristics are the following (ESIA, 2013):

- Indication of potential subsurface ancient structures: Identification of subsurface ancient infrastructures either dictate a restricting volume for ancient structures' protection define volumes above/below which the pipeline may pass. Soil characteristics can be used to assess the vulnerability of subsurface ancient structures to vibrations (Fig. 5, right).
- Avoidance of known cultural heritage sites through the project's design: Greek Law 3028/2002 (art. 13-14) provides for the creation of zones where specific activities may be granted under permit (Protection Zone B), or building is totally prohibited (Protection Zone A), both in archaeological areas beyond settlements, or on settlements which constitute archaeological sites.
- Recording of the condition and structural integrity of sites with components above ground in the vicinity of the project's footprint: This may imply definition of volumes within which vibration impacts on the structural integrity of a cultural heritage sites.
- Reduction of the pipeline's working strip: During construction phase, working strip is planned to extend 38 meters in width, with minimum depth of 1 meter, while it can be reduced up to 18 meters in specific cases (ESIA, 2013). Minimum working strip does not require to be symmetrical, allowing its widest side to extend up to 9.3 meters from the pipeline's centreline (ESIA, 2013) creating, a "working strip" volume which can be used to identify overlaps and compatibility with other PLRs on the same region, e.g. view (Fig. 5., left).
- Prohibition of constructions in areas of high archaeological potential inside the working strip, during very wet conditions: In such case, 3D zones of vibration impact

[1] Areas of high archaeological potential are considered the areas that may potentially include undiscovered sites (ESIA, 2013-Section 6).

can be defined, based on the depth of areas of high archaeological potential in wet conditions (Fig. 5, left).

4.5.5 Socioeconomic characteristics

The main 3D-related impact of TAP to socioeconomic characteristics within its development area refers to restrictions imposed on land tenure. Development of the pipeline is estimated to cross along 9189 land parcels, covering an area of 4277.7 Ha (TAP, 2016). Use of land is acquired either by land lease, or by establishment of servitudes, while a limited number of land parcels were permanently acquired. Impact on the affected parcels involves (Livelihood Restoration Plan):

- The establishment of a permanent PPS, (Zone A), after the pipeline's installation. Construction of buildings is forbidden within the PPS, while cultivation restrictions apply, based on plants' rooting-system depth (maximum allowed depth is defined at 30 cm, thus excluding cultivation of deep-root plants).
- Establishment of a 40-metre zone along the pipeline's centreline (Zone B), where physical structures will be restricted to greenhouses and pump houses for irrigation.
- A zone of 400 metres along the pipeline's centre-line (Zone C), where restrictions can be imposed to the number of buildings that can be constructed. Zone C restrictions are to be considered in case of elaboration of new urban Plans, or of modification of the existing ones.
- Increase of pipeline's installation depth in case of crossing already existing underground networks (Fig. 6).

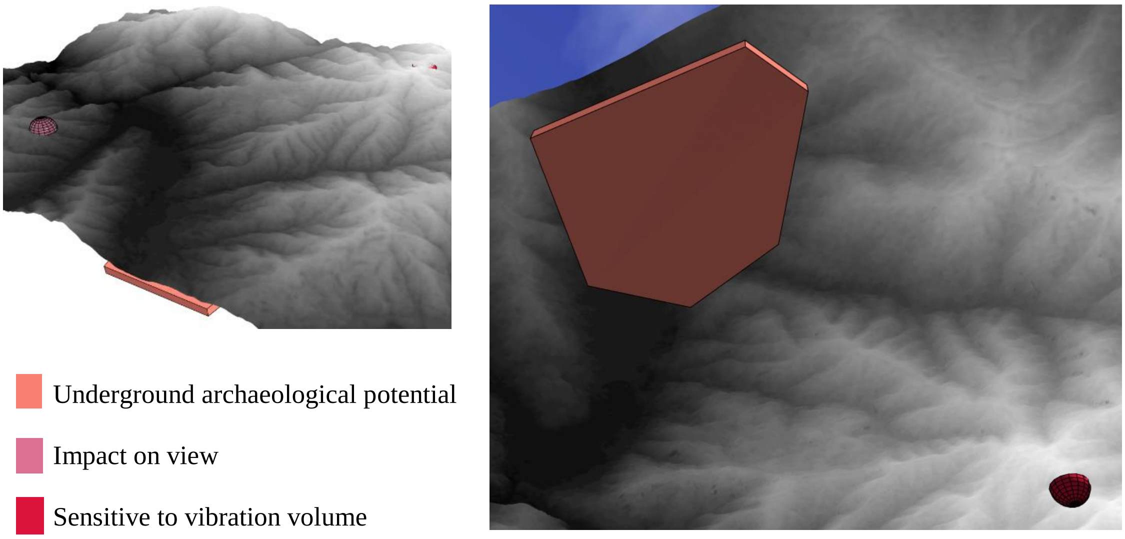

Figure 5. Archaeological PLRs from top (left) and bottom view (right) on DTM

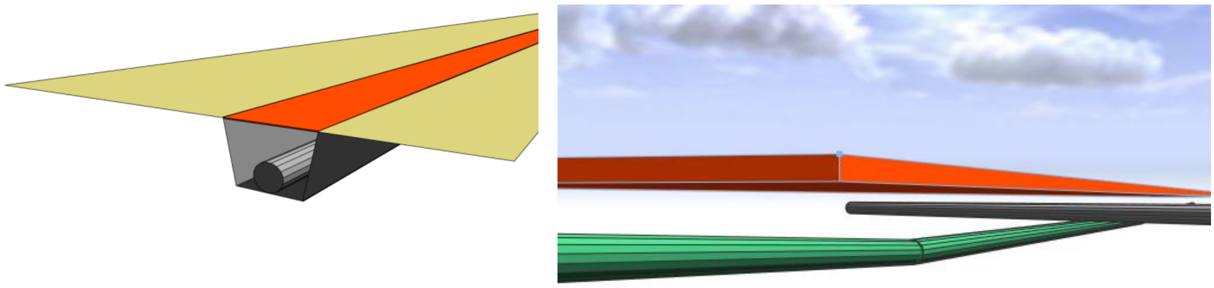

Figure 6. Left: 3D model of PPS (orange) and Zone B (yellow). Right: Crossing pipelines

4.5.6 Landscape and visual amenity

Development of the pipeline involves a variety of impacts or risks on landscape during all phases of its construction, which are influenced both by the natural landscape characteristics, e.g. forests, river crossings, areas of high landscape value, and by the project's characteristics, e.g. size of temporary and permanent installations (ESIA, 2013).

Mitigation measures to avoid landscape and visual amenity impacts, including 3D components, are the following (ESIA, 2013):

- Spare materials will be disposed permanently away from the pipeline's working strip to specified areas of minimal visual impact.
- Ensure that new earthworks integrate seamlessly with the existing landform, in the best possible manner.
- Design and location of above ground structures to be visually unobtrusive.
- Use of vegetation screens to reduce visual impacts in the long term, especially in case of compressor and block valve station parcels.

5. DISCUSSION AND CONCLUSIONS

Preceding sections depict the 3D character of a significant number of environmental PLRs. Environmental analysis and assessment comprise, not only physical environment, such as soil or groundwater, but extend to fauna and flora, protected areas and cultural heritage. Environmental protection measures within the context of ESIA comprise regulations of direct 3D characteristics (for example depth, height or volumetric restrictions), and regulations that apply to 3D space, but are based on non-geometrical physical characteristics, such as the dependence of groundwater protection on above-lying soil permeability. 3D PLRs based on qualitative characteristics can also be traced, for example in case of protection of intangible cultural heritage, or landscape.

Technical limitations still restrict 3D visualisation of physical environment and the benefits of such an approach are under debate (Lai et al., 2010). However, the development of PLR Cadastres and of environmental restrictions' registries, highlights the necessity of PLR recording. Environmental impact assessment requires analysis of 3D related characteristics, mainly exploiting charts, maps or descriptive evaluation criteria for the interpretation of environmental characteristics by different user groups. 3D analysis and presentation by current reports are mainly applied in case of landscape impact assessment, through GIS analysis and photomontage. Although aforementioned means of environmental

characteristics' presentation comprise of 3D components, evaluation, assessment and mitigation measures are not presented in 3D, while there are no requirements of mapping 3D restrictions.
Development of a 3D PLR Cadastre database, constitutes a challenging task with particular requirements, compared to contemporary cadastral databases. Of the most important considerations is selecting and defining the PLRs to be included in a 3D PLR Cadastre. Multiple land-related laws impose various restrictions on land that may not apply to 3D space, or may not be relevant to environmental protection, or require excessive resources to be modelled in 3D. Such restrictions need to be identified and excluded from the development of 3D PLR Cadastres. Quantification and determination in 3D space of qualitative characteristics is another important issue that needs to be addressed within the concept of 3D PLR Cadastre development. This requires collaboration between experts from different scientific fields and competent authorities, so that specific qualitative characteristics are defined in terms of 3D spatial regulations. 3D related requirements and mitigation measures of E(S)IA studies reflect the relevance of 3D defined PLRs to environmental assessment. Within this context, explicitly 3D defined legal regulations and restrictions on E(S)IA can be stipulated, while also requiring 3D documentation to be included in future E(S)IA studies and reports.

REFERENCES

Cadastre and Land Registry Knowledge Exchange Network (CLRKEN). (2015). Documentation of "Public Law Restrictions" - Results of the Questionnaire in Preparation for the CLRKEN Workshop in November 2015. Available online: http://www.eurogeographics.org/sites/default/files/151209-ResultsOfQuestionnaireForPLRCadastre.pdf (accessed May 2018).

Caldwell, L. (1988). Environmental Impact Analysis (EIA): Origins, Evolution and Future Directions. *Impact Assessment, 6*(3-4), 75-83.

Danese M., Las Casas G., Murgante B. (2008). 3D Simulations in Environmental Impact Assessment. In: Gervasi O., Murgante B., Laganà A., Taniar D., Mun Y., Gavrilova M.L. (eds) Computational Science and Its Applications – ICCSA 2008. ICCSA 2008. Lecture Notes in Computer Science, vol 5072. Springer, Berlin, Heidelberg.

Döner, F., Thompson, R., Stoter, J., Lemmen, C., Ploeger, H., v. Oosterom, P., & Zlatanova, S. (2010). 4D cadastres: First analysis of legal, organizational, and technical impact—With a case study on utility networks. Land Use Policy, 1068-1081.

Ducci, D., & Sellerino, M. (2013). Vulnerability mapping of groundwater contamination based on 3D lithostratigraphical models of porous aquifers. *Science of the Total Environment*, 315-322.

Environmental and Social Impact Assessment (ESIA) process in Greece. (2011). Trans Adriatic Pipeline, Available at: https://www.tap-ag.com (Accessed July 2018).

European Commission. (2017). Environmental Impact Assessment of Projects: Guidance on the preparation of the Environmental Impact Assessment Report. Available at: http://ec.europa.eu/environment/eia (Accessed July 2018).

Federal Office of Topography swisstopo. (2015). The Cadastre of Public-law Restrictions on Landownership (PLR-cadastre). Available at: http://www.cadastre.ch (accessed June 2018).

Givord, G. (2012). Cadastre 3D des Restrictions de Droit Public à la Propriété Foncière. *MSc. thesis*, 73.

Glasson, J., Therivel, R., & Chadwick, A. (1999). *Introduction to Environmental Impact Assessment.* UCL Press.

Gonzáles, A. (2012). GIS in Environmental Assessment: a Review of Current Issues and Future Needs. *Journal of Environmental Assessment Policy and Management, 14*, 12500071-125000723.

Heldak, M., Szczepański, J., & Patrzałek, C. (2012). Using the 3D Computer Scanning Method in the Environmental Impact Assessment. *Infrastructure and Ecology of rural areas*, 49-59.

Kitsakis, D., & Dimopoulou, E. (2016). Investigating Integration of Public Law Restrictions to 3D Cadastre. *5th International FIG 3D CadastreWorkshop*, (s. 25-46). Athens, Greece.

Kitsakis, D., & Dimopoulou, E. (2017). Addressing Public Law Restrictions within a 3D Cadastral Context. *ISPRS - International Journal of GeoInformation*.

Kitsakis, D., & Papageorgaki, I. (2017). Towards 3D Modelling of Public Law Restrictions in Water Bodies. *European Water*, 395-401.

Kurakula, V. (2007). A GIS-Based Approach for 3D Noise Modelling Using 3D City Models, MSc Thesis, International Institute for Geo-Information Science and Earth Observation, Enschede, The Netherlands.

Lai, P. C., Kwong, K.-H., & Mak, A. S. (2010). Assessing the applicability and effectiveness of 3D visualisation in environmental impact assessment. *Environment and Planning B: Planning and Design, 37*, 221-233.

Navratil, G. (2012). Combining 3D Cadastre and Public Law – An Austrian Perspective. *Proceedings of the 3rd International Workshop on 3D Cadastres: Developments and Practices*, (s. 61-72). Shezhen, China.

Ngo, L., tsang, T., & Wong, C. (2014). 3-dimensional EIA – A Greener Tool to Plan and Design. *Impact Assessment for Social and Economic Development*, (s. 1-6). Viña del Mar, Chile.

Sheng, N. (2011). Prediction and 3D Visualization of Environmental Indicators: Noise and Air Pollution, MSc Thesis, Royal Institute of Technology (KTH), Sweden.

Siouti, G. (2011). *Environmental Law*. Athens-Thessaloniki: Sakkoulas Publications.

Stoter, J., de Kluijver, H. and Kurakula, V. (2008). 3D noise mapping in urban areas, International Journal of Geographical Information Science, 22:8, pp. 907-924.

TAP. (2016). Livelihood Restoration Plan (Greece).

United Nations Environment Program (UNEP). (2002). EIA training resource manual. Available at: https://unep.ch/etb/publications/EIAman/SecETopic6.pdf (accessed July 2018).

United Nations. (25. September 2015). *Sustainable Development Goals*. Available at: https://www.un.org/sustainabledevelopment/sustainable-development-goals/ (Accessed July 2018)

US Geological Survey (USGS) website. Available at: https://water.usgs.gov (accessed July 2018).

Vandysheva, N., Ivanov, A., Pakhomov, S., Spiering, B., Stoter, S., Zlatanova, S. and van Oosterom, P. (2011), Design of the 3D Cadastre Model and the Development of the Prototype in the Russian Federation. *2nd International Workshop on 3D Cadastres*, (355-376). Delft, the Netherlands.

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