Adjusting the 2D Hellenic Cadastre to the Complex 3D World – Possibilities and Constraints

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Key words: Hellenic Cadastre (HC), 3D Cadastre, Hybrid Cadastre, Property Objects, 3D Right Objects

SUMMARY

The Hellenic Cadastre (HC) collects information on property objects, in order to cover the entirety of the Greek territory and according to its action plan, this information is in reference with the land-parcel and is analyzed on the two dimensions of the real objects. However, according to Dimopoulou et al (2006), registering property objects in the three dimensional space has become an imperative need in order to optimally reflect all complex cases of the multilayer reality of property rights. Furthermore, according to Papaefthymiou et al (2004) the current developments in social, technological and economical aspects of modern life require Cadastral systems with 3D enabled geometrical and topological models for property registration. However, implementing the 3D concept in the present Cadastral system does not imply the establishment of an absolute three-dimensional registration system, which is not currently feasible. The hybrid Cadastre seems to be the optimal approach for the complex Greek reality, because it involves maintaining the current 2D Cadastre, while simultaneously incorporating the registration of three-dimensional cases and the integration of 3D data types.

In this paper, we refer in detail to the characteristic cases, which require three-dimensional visualization. We also evaluate characteristic features of the HC Project (HCP), as well as its progress while indicating the shortcomings of the current cadastral system. Furthermore, we include promising future plans of the scientific personnel of the HC in order to create a more sophisticated and sufficient cadastral model in line with the cadastral project. In our attempt to examine, analyze and transform the conceptual and the logical model of the existing Hellenic Cadastre DataBase (HCDB), we focus our attention on the adjustments that must occur to the cadastral model in general in order to succeed in the smooth and feasible transition to a hybrid model. Based on the international experience (e.g. the Netherlands) we implement a prototype of a 3D Cadastre, in which, according to Stoter and Ploeger (2002), rights established on 2D parcels can be represented in 3D, improving accordingly, the insight in the vertical component of the rights. Examples of the rights of these objects in the characteristic cases we mentioned above are modified in the ArcScene environment. In addition, we indicate the necessary reforms that ought to be considered in our institutional and legislative cadastral registration's framework while, simultaneously, we thoroughly examine the contradictions derived from the existing Civil Code and Customary law. Finally, we conclude what the prospects for this implementation are, in a promising and mostly feasible way.

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1. INTRODUCTION

According to the action plan of the Hellenic Cadastre (HC), the cadastral system which currently applies to the Greek territory is in fact a two-dimensional registration system, while property is the core of the organization and quest of the legal information. Cadastral systems such as the above have proved to be moderately sufficient and adequate in most conventional situations worldwide. However, according to Zentelis ("Concerning Land Matters and Cadastre", 2011) this type of registration system can no longer portray the contemporary and evolving more complex-structured environment satisfactorily, in which cases of development and multiple use of space, as well as the layered distribution of rights is prevalent.

Thus, defining a multilayer and three-dimensional cadastral model has become an imperative need in order to reflect and register the ownership with consistency in accordance to three-dimensional reality. According to Dimopoulou et al (2006) the basic stages towards the transformation from 2D to a 3D cadastral model are:

- analysis of the Hellenic Cadastre DataBase (HCDB);
- specifying the application's environment and selecting the adequate software;
- transformation of the real estate object's geometry from 2D to 3D;
- creation of a 3D prototype for the registration of 3D properties.

Additionally, we consider certain technical as well as legal aspects of the HC in order to analyze the cadastral system at all levels of modeling, and we refer to the international experience in order to adopt the reforms and developments which appear to be suitable for a 3D application to the Greek model.

2. NEED FOR 3D REGISTRATION

The implementation of a three-dimensional cadastral model in Greece has become a necessity especially in urban built-up areas, since it displays the allocation of ownership rights in the vertical component sufficiently. Besides, the Hellenic Cadastre is responsible for registering:

- land-parcels;
- condominium;
- vertical ownership;
- composite vertical property ;
- special Real Property Objects (SRPO);
- mines.

These objects can only be portrayed by making use of the third dimension which enables their location on, below or over the earth's surface.

In addition, the registration of the 3rd dimension by the HC is a necessity considering:

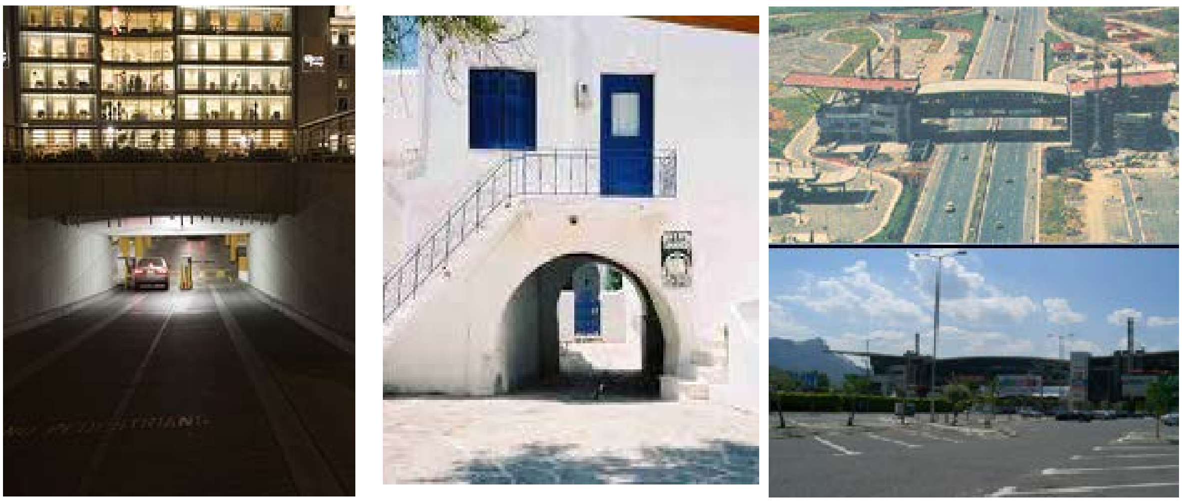
- the intense relief of the land, resulting in complex constructions, multi-level buildings and the entanglement of property areas for different (independent) properties. (Papaefthymiou et al, 2004);
- the inadequate area of Greek land combined with increasing urbanization, has led to the emergence of multilevel constructions;
- the great historical value of the Greek land, on which unfortunately, many modern settlements are built on the ruins of ancient cities;
- the registration of Special Real Property Objects;
- the registration of customary property rights;
- the contradictions in Greek legislation concerning three-dimensional objects, such as condominiums;
- urban planning purposes. A 3D cadastral model would be sufficient in displaying the precise legal situation within the buildings and in detecting infringements of General Building Code (GBC);
- fiscal and real estate considerations, since the land value is high, especially in urban and commercial areas.

2.1 Cases requiring 3D registration

There are multiple examples of properties requiring 3D registration as well as 3D representation within the Greek territory. These characteristic cases are presented below:

2.1.1 Overlapping Private and Public Properties

- Public properties over, below or on private areas
- Private properties over, below or on public areas



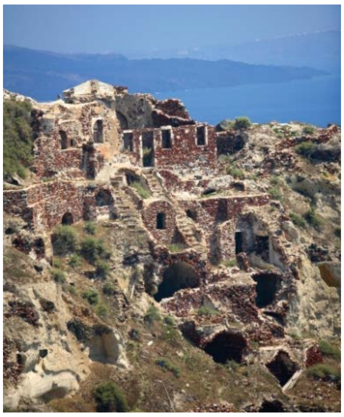
(a) (b) (c)

Figure 1. (a) private parking lot below public area, (b) public arcade below private property (anogeio), (c) private construction over national highway

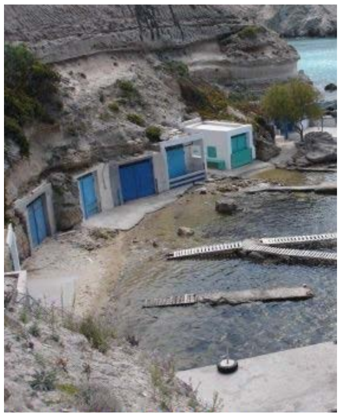
2.1.2 Special Real Property Objects, such as

- Anogeia (high-level constructions built, some bridging roads or paths, very common on Greek islands and traditional villages) (see Figure 2(a))
- Katogeia (constructions built below ground-level)
- Yposkafa (houses which have been dug-in, or hewed into the earth, which is common on many Greek islands) (see Figure 2(b))
- Syrmata (typical seaside spaces common on islands of Cyclades, which have a special mechanism to draw the boats inside during the winter) (see Figure 2(c))
- Mines, extending under the earth's surface
- Arcades
- Tanks
- Wells
- Arches (structure spanning a space while supporting weight) (see Figure 2(d))
- Windmills (see Figure 2(e))
- Domes (Byzantine constructions functioning as large warehouses) (see Figure 2(f))

(a)



(b)



(c)

(d)

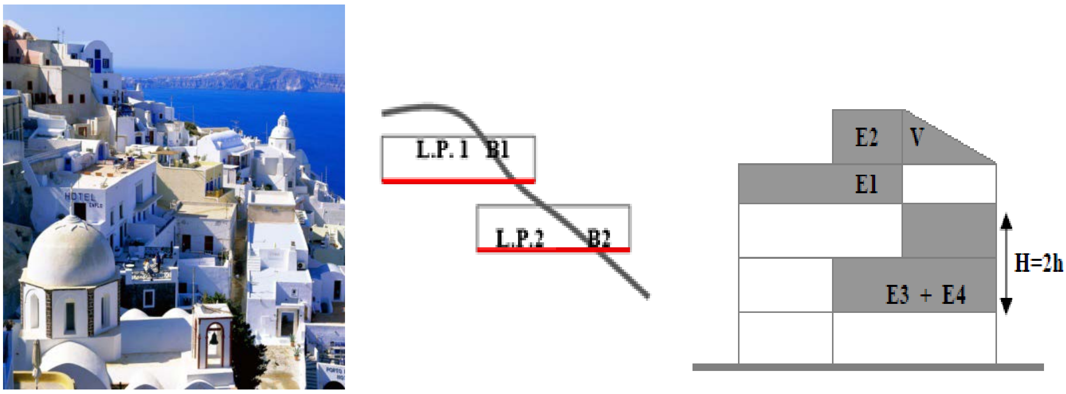
(e)

(f)

Figure 2. (a) Avogeio, (b) dug-in houses, (c) syrmata, (d) arch, (e) windmills, (f) domes

2.1.3 Overlapping Private Properties

In many Greek Islands (e.g. in Santorini or Syros), properties are partially or totally overlapping to each other as shown in Figure 3(a) (b). According to Dimopoulou et al (2006) these property rights are mainly based on customary laws, that regulated the transfer of property from one generation to the next, resulting in the structure of the type of property devolved.



(a) **(b)** **(c)**

Figure 3. (a) Overlapping real estate objects in Santorini , (b) The horizontal projections of land parcels 1 & 2 and buildings 1 & 2 are overlapping, (c) "Unusual" exploitation of multilevel buildings

2.1.4 "Unusual" exploitation of multilevel buildings

According to Dimopoulou et al (2006) there are many cases of multilevel buildings in which, privately owned space of apartments has diverse heights, different from the "standard" (three meters), due to special constructions, such as lofts and top roofs. As shown in Figure 3(c) the third and fourth floor's apartment is registered as E1+E2 concerning area, although it extends to the unregistered area of the roof and the first floor's apartment, with total registered area E3+E4 has double height above space, which is not registered.

2.1.5 Condominium rights

2.1.6 Infrastructures below private properties

3. INTERNATIONAL EXPERIENCE

In the past decade various activities have been conducted related to 3D Cadastres and the implementation of a multidimensional 3D cadastral model worldwide. The start of the international awareness of this topic was marked by the workshop on 3D Cadastres (sponsored by FIG Commissions 3 and 7), organized by Delft University of Technology in November 2001. This was followed by a session virtually during every FIG working week and congress from then onwards. However, no country in the world yet to develop a fundamentally three-dimensional cadastral system.

Nevertheless, there are several countries which have resolved key issues of the 3D registration of properties, especially in legal terms. In order to take into consideration the state of the art so far, we examine and analyze the management and manipulation of 3D cases, in legal and technical terms, based on the questionnaires related to 3D Cadastre in the Netherlands, Australia (Queensland) and Israel, countries which are pioneers in this vision. Finally we refer to the Greek case in order to indicate the main drawbacks of the Greek Cadastral model.

3.1 The Netherlands

General/applicable 3D real-world situations:

- Available example descriptions of typical 3D parcels in deeds registered in the public registers, which describe 3D objects in a 2D way.

Infrastructure/utility networks:

- Registration of the networks' ownership as legal objects.
- The network structure traceable in the DCDB as physical objects (network charts recorded in the public registers show the relation between the 'course' of the network and the 2D cadastral map).
- Available example descriptions of typical 3D parcels for networks.
- Intersecting networks or vertically parallel networks represented on the network chart by different colors or gray-scales.

Construction/building units:

- Registration of 3D construction-building units, but not as 3D objects (e.g. apartment units and superficies rights).
- Available prototype 3D parcels (not registered in 3D).

DCDB (The Cadastral Database):

- No representation of 3D parcels, but attribute values of parcels may indicate a 3D situation (i.e. pollution, mining, right of ease, underground construction).
- Representation related to the corresponding 2D parcels through their geometry.
- Networks represented as lines.
- Oracle Spatial DBMS software and Fingis (future Intergraph Geomedia). No 3D capabilities included.
- No possibility of storing 3D parcels' geometry, or managing a 3D topological structure.

3.2 Australia, Queensland

General/applicable 3D real-world situations:

- Available generic legislation for 3D descriptions of parcels (Land Title Act 1994).

Infrastructure/utility networks:

- Registration of network parcels in some cases.
- The network structure no traceable traced in the ACDB (networks are broken at the surface parcel, and may not be defined below roads etc.)

Construction/building units:

- Registration of 3D construction/building units (building units for residential or commercial purposes).
- Available example descriptions of typical 3D parcels, stored in ACDB, with no graphical extent (just the unit number and the surface area of each unit).

DCDB (The Cadastral Database):

- Representation in the ACDB of 3D parcels as 2D polygons in a layer above or below the base layer.
- Presentation in cadastral maps as polygons is a contrasting color to the base parcels.

- CDB is organized as object-oriented (but with layer as an attribute).
- 3D objects queried as all other objects, (but with only the 2D footprint returned).
- Ingres DBMS software and Microstation. No 3D capabilities included.
- No possibility of storing 3d parcels ‘geometry, or managing a 3d topological structure.

3.3 Israel

General/applicable 3D real-world situations:

- Available R&D report which includes a proposal for regulations for 3D descriptions of parcels
- Available example descriptions of typical 3D parcels.

Infrastructure/utility networks:

- Registration of network parcels in the near future
- Network structure will be traceable in the ICDB as "super positioning" of 3D sub parcels
- Available prototype 3D parcels for networks

Construction/building units:

- Registration of 3D construction/building units (theoretically any type of construction.)
- Available prototype 3D parcels (not registered in 3D).

DCDB (The Cadastral Database):

- Organized as multi-layers
- No representation of 3D parcels, as 3D CDB is not yet available.
- Introducing 3D storage and representation capabilities, as well as 3D topological maintenance capabilities in the CDB in the near future.

3.4 Greece

General/applicable 3D real-world situations:

- No example descriptions of typical 3D.
- No generic legislation for 3D descriptions of parcels.
- Natural resources (mining rights) considered as 3D parcels (Mines have spatial representation in distinct thematic polygon layers).

Infrastructure/utility networks:

- Networks are recorded and managed by the responsible (private or state) organization.

Construction/building units:

- Registration of 3D construction-building units, but not as 3D (e.g. apartment units recorded in attribute fields).
- Available example description of typical 3D parcels (not registered in 3D).

DCDB (The Cadastral Database):

- No representation of 3D parcels
- Relational DBMS Oracle 10g software and ArcGIS .No 3D capabilities included.

It is obvious that the Greek Cadastre has a long way to go and has a lot of issues to resolve in order to be able to adopt aspects of the 3d reality in the future. On the other hand, so far no country has developed a substantial 3D cadastral model, but most of them have resolved key issues concerning 3D registration or representation of 3D cases even in 2D. Besides, an adequate 3D representation of the cadastral data -and especially characteristic cases- is still a long way to come, since the contemporary DBMS have no 3D capabilities included, both in terms of topology and geometry. In the future these issues might be resolved and the 3D cadastral systems will become a reality.

4. HELLENIC CADASTRE

Under these circumstances, realizing the Greek Cadastral model efficiently, requires a thorough analysis of the *two phases of data modelling*, specifically the conceptual and the logical design of the model.

4.1 Cadastral model

4.1.1 Conceptual model

According to the international standards, the Hellenic Cadastral model is organized on the following scheme (Figure 4) e.g. person-right-real estate object. In addition, appurtenances accompany the real estate objects, while deeds proving the right accompany the right itself.
The conceptual model of the two dimensional cadastral model is organized in reference with the land parcel (parcel-based), which additionally contains rights applying on the parcel.
The conceptual data model of the HC project was designed using Entity Relationship diagram (ER), which separates the object of interest in entities. Entities are characterized by attributes and interrelated relationships (Stoter and van Oosterom, 2006). The relationships between the entities in the greek cadastral database are described with text and are implemented in the database. The spatial model of the operating Cadastre can be seen below (Figure 5).

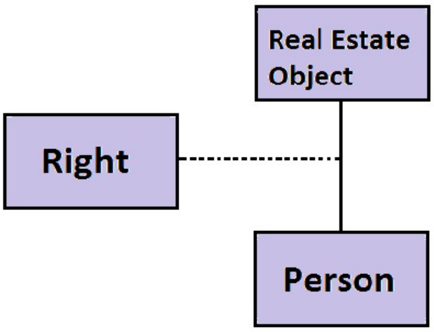


Figure 4. Cadastral data model

4.1.2 Logical model

During the logical design, the conceptual model is translated into the logical model and, in particular, into a data model of a specific DBMS type (Stoter and van Oosterom, 2006). The Greek Cadastre uses relational DBMS Oracle 10g, thus the logical model is basically relational concerning the actual database, although it contains additional object-oriented applications.

4.2 Cadastral database

Within the cadastral database, data are organized into logical sections as shown below:

– digital spatial database: a) Thresholds of administrative division, b) land-parcels c) buildings, d) mines, e) sites of exclusive use, f) easements, ζ) platforms (True-orthophotos, DSM, topographic drawings);
– digital descriptive database: a) registered rights and titles, b) beneficiaries, c) operations, d) requests, e) right-objects.

The spatial data are stored in the database and are visualized with ArcGIS server of ESRI, Openlayers API or WMS (Web Map Service), as well as javascript browsers. In addition, applications for CAD users are available. Finally, the descriptive information is maintained in the database Oracle 10g and is visualised with Microsoft.net.

Under these circumstances, we realize that we do have the relevant expertise and technical resources to support the management of 3D characteristic cases in the database, although we need to take into consideration the current cadastral reality and its constraints.

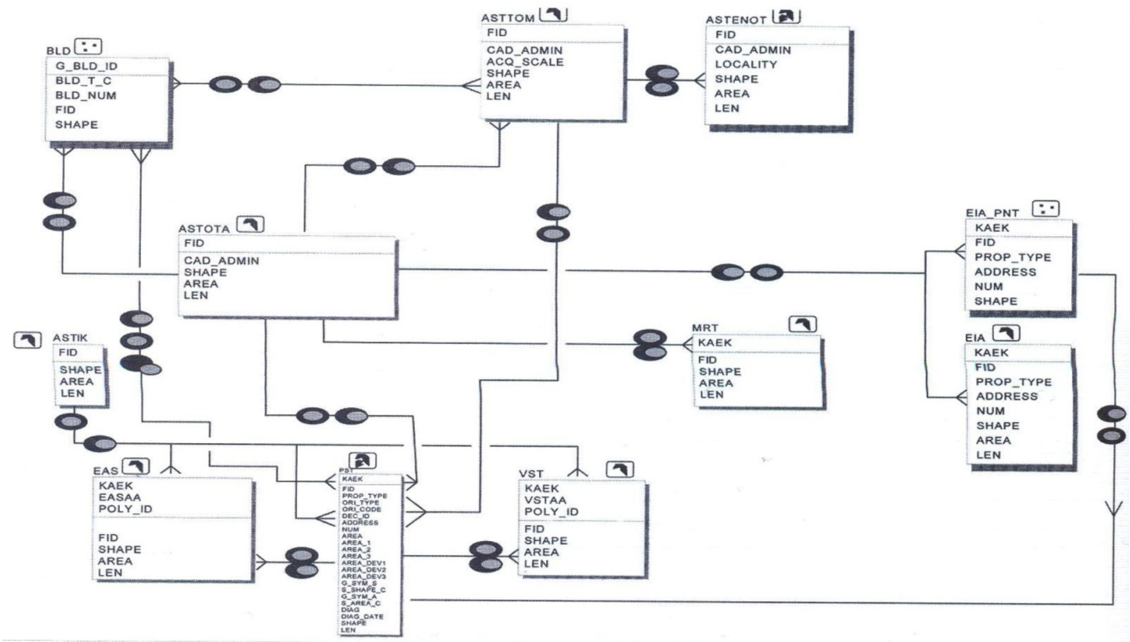


Figure 5. Spatial model of the operating Cadastre

4.3 Cadastral reality and constraints

It is evident that the implementation of a 3D cadastral model in Greece requires the resolution of certain fundamental issues underlying the operating cadastral system, which inflate over time. In general, the current Cadastre refrains from the principles of electronic services that must govern every cadastral system for its optimal operation. In particular:

– The spatial database contains the information of buildings, however neither the outlines or the footprints of them can be traced on the cadastral maps. Additionally, the spatial model (illustrated in Figure 5) includes an extra entity related to buildings, thus it is in fact possible to represent the outlines of the buildings, but this function hasn't been implemented so far. The main drawback of the greek model is that it only involves the legal information on properties, excluding the representation of the distribution of rights in 2D space. The main reasons for avoiding the spatial visualization of buildings are:
  – to avoid legitimizing the arbitrary constructions of any use;
  – collecting information related to buildings can be very expensive, since it must be controlled by surveying processes. It is worth mentioning that during the cadastral survey back in 2003, only the facades of buildings were collected in each building block , while their outlines were realized with virtual polygons. Later on, this

practice was also abandonded since the information registered was inefficient and false.

- The Special Real Property Objects we analyzed in the previous chapter, concerns a plethora of objects, which are characterized by mutliple and complex topological relations applying between various properties and are the only 3Ds managed in the existing cadastral model. According to the HC project, they are manipulated not as spatial information but as descriptive. Therefore, during the cadastral survey, the surveyors contractors who had been assigned by the HC to register these objects were forced to attach a relational / topological matrix to the deliverables of the survey, which would include the description of these objects in a structured descriptive manner using words such as ''above'' or ''below''. No original specifications related to the registration of the S.R.P.O. were provided by the HC, therefore surveyors manipulated various methods to obtain the required information related to these items:
  - most contractors delivered the topological matrix alone, *without delivering spatial representation* of the objects, since the HC project hadn't provided original specifications for their registration. In this case, the S.R.P.O. are defined as parcels in a descriptive manner. In particular, they are described with a 12-digit Cadastral Number fixed by the HC, accompanied by a special comment, indicating the cadastral numbers of the other parcels, whith which they are involved;
  - some contractors delivered the *topological matrix* along with some rudimentary spatial information concerning the S.R.P.O. In particular, the S.R.P.O with no percentage of ownership on the land-parcel e.g. anogeia or katogeia, were usually not spatially traced in the cadastral model. In these cases, surveyors collected the entries of the objects, which can currently be traced in the cadastral map as points, which represent servitudes, entries or access to a katogeio, anogeio etc.;
  - some contractors delivered *topological matrix along with spatial depiction*, which can currently be traced on the cadastral maps using polygons in a different thematic layer than the parcels. In some of these cases, a topografic plan or a draft plan was also attached in the deliverables;
  - finally, some contractors *didn't even deliver* the topological matrix;
  - most contractors *exported data* from the available deeds or titles.

  We realize that these methods are insufficient in representing the distribution of rights for the S.R.P.O. in the vertical component, while they cause further confusion on the issue of the registration of these objects.
- Features of the three-dimensional nature of the properties, such as the buildings' floors in the case of horizontal ownership, are only registered as an attribute or descriptively. Moreover, the deeds or titles do not contain floor plans of the apartments. The information currently collected is the building's code, the floor and the property's Cadastral Number.
- There is no capability for the maintenance and updating of spatial data, since the current ownership status is not efficiently registered in the cadastral system, while the linking between descriptive and spatial data in the database is limited to the Cadastral Number.

4.4 Land Registry

The system for recording land rights in Greece was (and still is, unless superseded by the Cadastre) the registration of deeds, operated by the so-called "Mortgage (or Hypothecs) Offices". Under such a system, a copy of each deed of transfer of property rights is deposited in the deed registry in a chronological order. The registry is supplemented by a land charge register, which provides information about charges, mortgages, real servitudes and property claims. In addition, an index of names of vendors, of purchasers and of claimants is provided, related to the Volume and folio in which the deed is registered. The registration of parcels is usually coupled with an extensive verbal description of boundaries or/and a graphical plan, attached to every transaction, obligatory since 1977 and deposited to the Notary Public (Zentelis & Dimopoulou, 2001). In regions where the cadastral survey remains in progress, Land Registry Offices are still valid, operating alongside with the corresponding Cadastral Offices. Besides, the legal definition of real property provided by the old system does not always reflect the actual condition on the terrain and this situation creates further confusion in the manipulation and management of land issues within the Greek territory and best evidence cannot easily be proved. In particular:

– Deeds do not contain 3D information related to the heights applying on real estate, but relevant descriptive information. The only exception is when the legal description in deeds is accompanied by topographical plan including coordinates and/ or heights.
– Land Registry Offices retained legal information related to land parcels and this information was (and still is) updated by new deeds describing recent transactions on real property. Similar problems apply for the HC project, since only the legal information is updated, while there is no capability for local offices so far, to maintain and update spatial data.

4.5 Future plans

In contrast to the above issues, the future plans of the HC project advocate for the resolution of these issues and the implementation of important measures resulting in the improvement of the cadastral model in order to adopt efficiently the international developments and to adequately depict the complex three dimensional reality. In particular:

– The HC will cooparate with the Ministry of Environment and Development and the Hellenic Technical Chamber for the spatial registration of buidings on the greek territory.
– Further study of the Cyprus Cadastre as well as its specifications and principles in order to resolve issues (related to the conclusiveness of the Greek Cadastre as well as the principles of e-Government and maintenance of data) operating HC, which hinder its smooth functioning.
– Consideration of LADM (Land Administration Domain Model)
  LADM is an international standard set by the international standards organization (ISO) and the technical committee on geographic information of European Committee for Standardization and is basically a fundamental attempt to standardize the cadastral systems worldwide. The HC project hasn't adopted LADM, however they intend to proceed with further study and possibly incorporate it accordingly to the greek cadastral model in the near future.

5. 3D CADASTRE IN GREECE

Under these circumstances we realize that it's not yet possible to adopt a full 3D cadastral system, therefore the hybrid 3D model seems to be feasible and the optimal solution for the Hellenic Cadastre. Besides, referring to a hybrid conceptual model, it involves the maintaining of the current 2D Cadastre, while simultaneously incorporating the registration of three-dimensional cases and the integration of 3D data types in every case necessary.

Based on international experience (e.g. the Netherlands) we implement a prototype of a 3D Cadastre, in which, according to Stoter and Ploeger (2002), rights established on 2D parcels can be represented in 3D, improving accordingly, the insight on the vertical component of the rights. These are acquainted as 3D right-objects or 3D right-volumes, and they basically are a three dimensional representation of rights on two dimensional land parcels and they constitute 3D registration of rights. Developing these objects accordingly, in technical terms and especially in terms of topology, and visualizing them even as simple polyhedra, seems a challenging task and at the same time, the most appropriate 3D approach. In addition, we can successfully apply them in several cases of the complex Greek reality. Their representation will be achieved through the following methods, which vary according to the case study.

5.1 Buildings

One of the characteristic cases of rights, which require 3D representation is the establishment of horizontal ownership, most commonly in the case of apartments. As mentioned above, the deeds or the titles do not contain floor plans of the apartments, while the information currently collected by the HC is the builidng's code, the floor and the property's code (Cadastral Number). Under these *circumstances*, we initially need to attribute the buildings' outlines which are not represented on the cadastral map, in order to be able to visualize them in 3D.

– We collect the outlines of buildings from the initial records of the cadastral system in blocks ,where horizontal ownership has been established. Following, we collect information related to the number of the storeys from the deeds(contracts) or the descriptive data of the Hellenic Cadastre and we check the building's perimeter compared to the VLSO and the LSO. Finally, we can pose a conceptual value of the height per floor (e.g. 3 meters), in order to create the building's volume. We act accordingly in the case where a surveying plan is included.
– In areas where DSM is available by the HC project, we export heights and we pose a conceptual value of the height per floor (e.g. 3 meters), in order to represent the real estate objects in 3D .This way, we estimate the number of the storeys within the building. We check the building's permeter using the VLSO and the LSO which are provided by the HC project.
– In the case of unconventional exploitation of multi-storey buildings, where an attic or a loft exists, it's a necessity to have floor plans in order to represent the ownership status in the vertical component precisely.
– In the case where a floor plan is included along with the heights in the deeds, we use the coordinates and the true heights in order to create the building's volume.

5.2 Special real property objects

Special real property objects are described by various and complex topological relations between various propeties, which are not defined spatially but in a descriptive manner. The precise spatial representation of S.R.P.O. can be achieved performing the following:

- The most basic intervention we can perform in the cadastral model, using the existing data provided by the HC, is in the case where the surveyor/contractor delivered topological matrix along with spatial visualization (polygon or point). In this case, we can export relational heights from the topological matrix and we perform z-ordering. Following, we set height values comparable with the properties, thus we have an insight of the establisment of rights vertically.
- In areas where the DSM is available by the HC, we export heights and we compare with the topological matrix. Following, we pose a conceptual value of the height per floor in order to represent in 3D the real estate objects.
- In cases where the surveyor/contractor delivered a topological matrix without including spatial representation, field measurements must be performed in the area in order to obtain the construction's outline.
- In case we aim to perform an accurate 3D representation of a complex special real property oblect (e.g. dug-in house), which is spatially represented in the H.C 's cadastral maps, we have to carry out field measurements using HEPOS (Hellenic Positioning System) in order to obtain the construction's height.

In any case, we must import z-values in the database in order to store and manipulate 3D objects or 3D data types in general, within the cadastral model. In particular, we can create an additional field in which a list with z-values will be available, which provides the descriptive feature of the 3rd dimension. Futhermore, we can perform some reforms in the spatial data model of the HC in order to manipulate 3D data types. As shown in Figure 5, the spatial model includes an extra entity related to buildings, thus we can change the geometry of the data from 2D objects to 3D objects.

5.3 Greek cases studied

Examples of these right-objects on the characteristic cases we mentioned above are modified in the ArcScene environment. The HC provided us with the adequate raster and vector data, specifically VLSO, LSO, the parcels' shapefile and the S.R.P.O shapefile. We used the VLSO and the LSO as backgrounds, in order to create the constructions' footprints and we exported selected data from the parcels'shapefile in the selected areas. In addition, we exported data from the S.R.P.O. shapefile which were either polygons or points. Finally we added the additional field "height" in the attribute tables in ArcScene for each case studied, in which we provided a list with z-values. The result of the application is a 2D cadastral map, since it involves the maintenance of the current 2D Cadastre, while simultaneously incorporating the registration of three-dimensional cases and the integration of 3D data types when necessary.

The results of this effort are summarized as follows:

5.3.1 Overlapping private and public properties

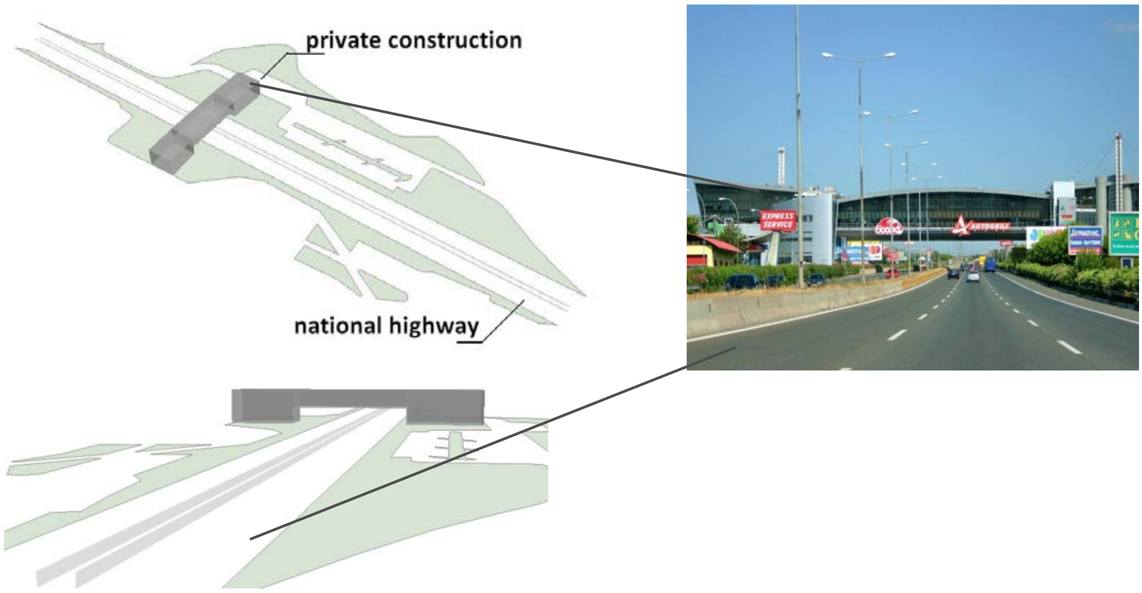


Figure 7. Private construction over national highway

5.3.2 Overlapping public properties and infrastructures

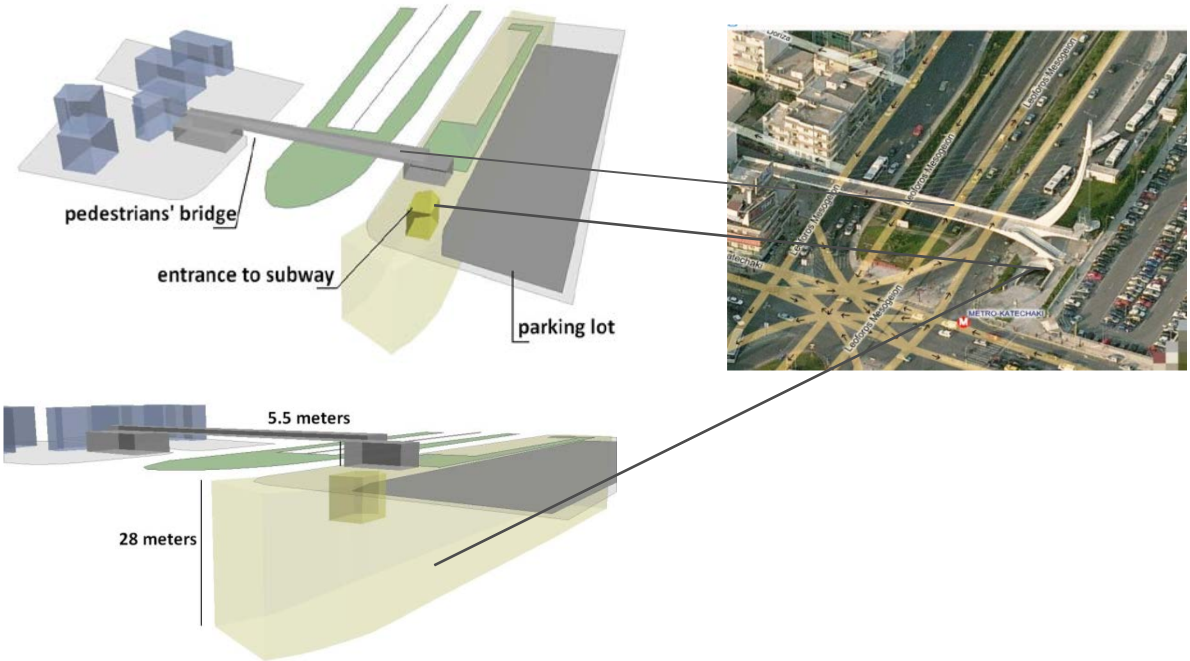


Figure 8. Avenue below pedestrians' bridge and over subway

5.3.3 Arcade

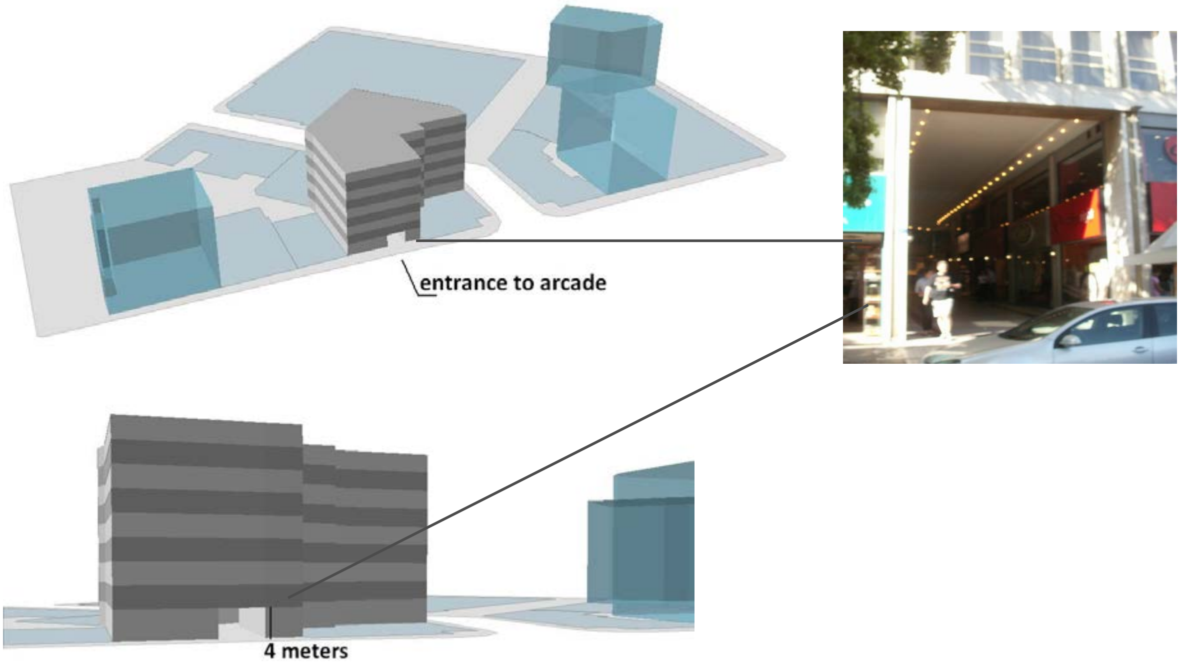


Figure 9. Public Arcade in Athens

5.3.4 Privately-owned semi-basement shops

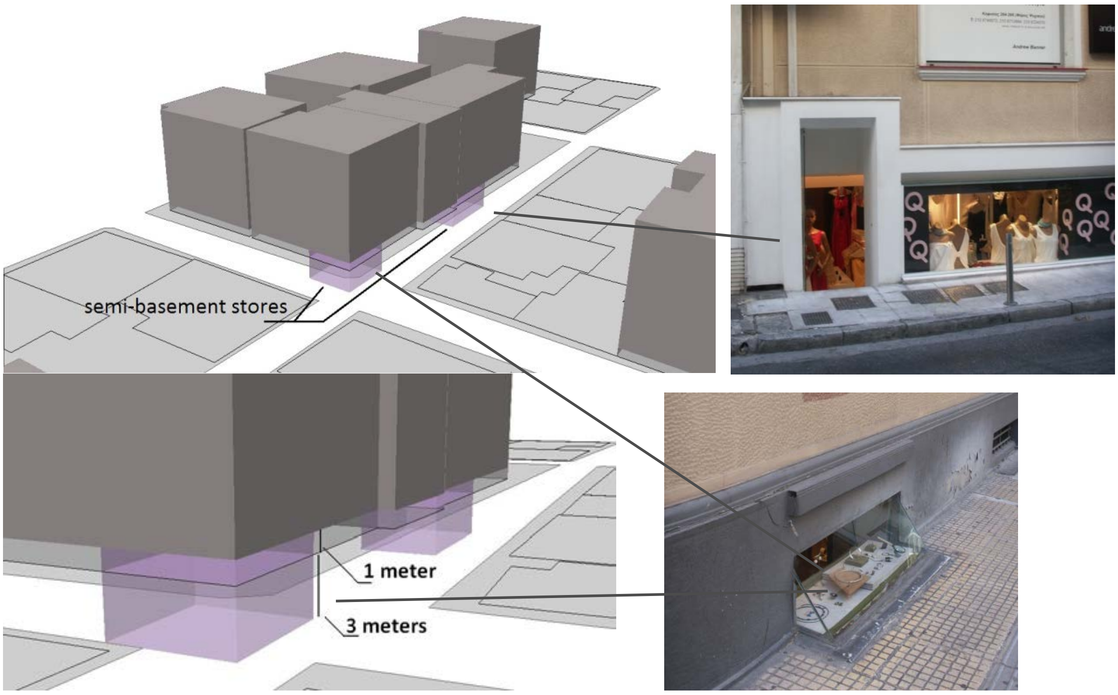


Figure 10. Semi-basement shops in Kolonaki

5.3.5 Multi-storey buildings

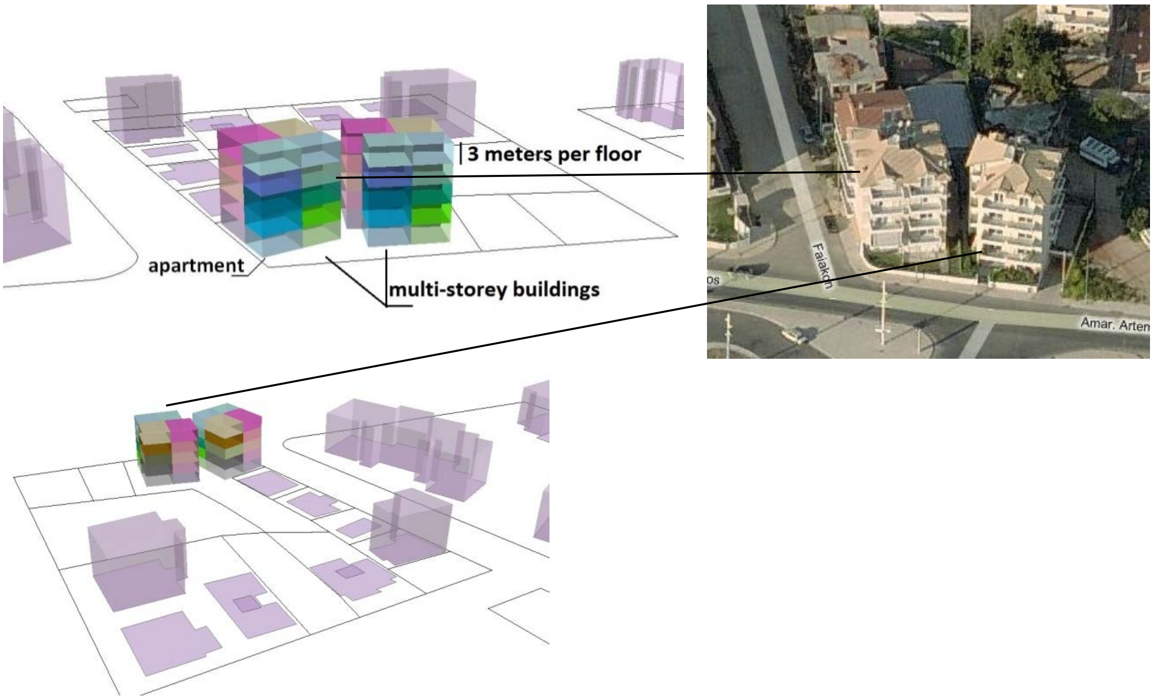


Figure 11. Apartment rights are represented with different colors in multi-storey buildings

5.3.6 Anogeia

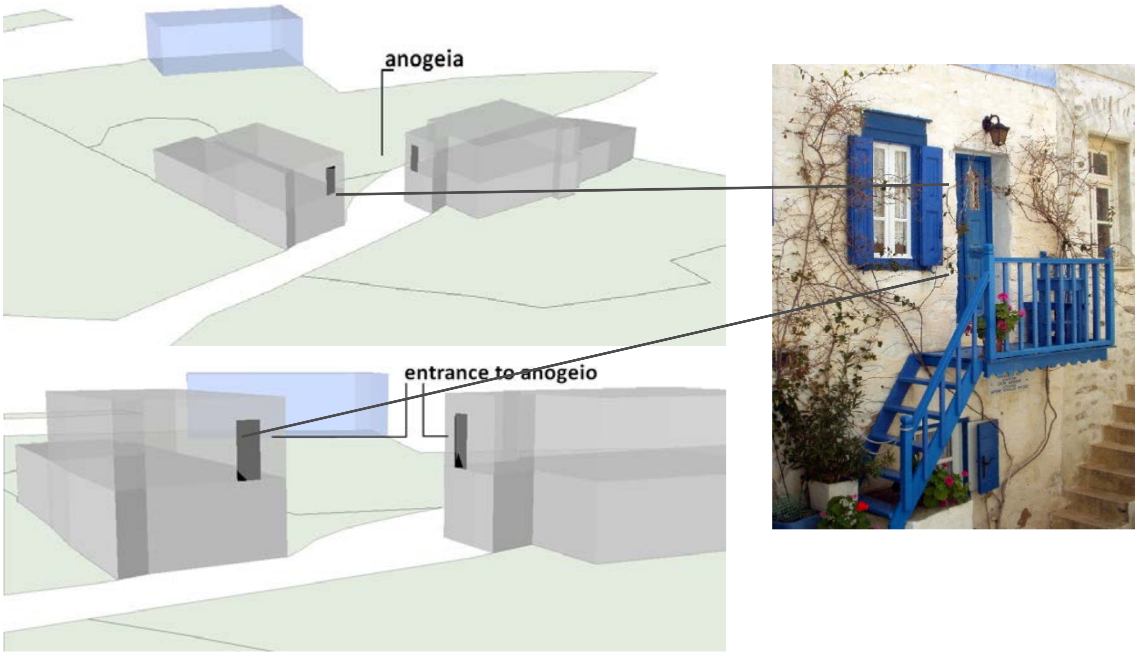


Figure 12. Anogeia in Syros

5.3.7 Privately-owned store with loft

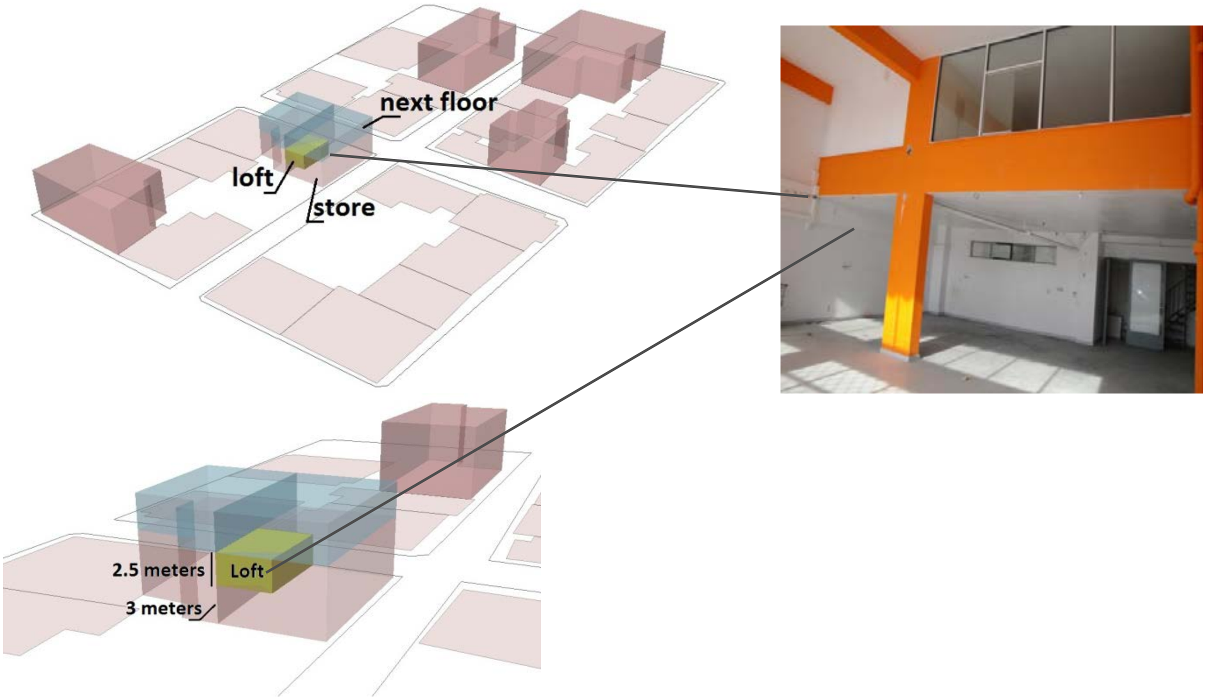


Figure 13. Loft within a store

6. LEGAL FRAMEWORK

The core laws governing the HC project for the registration of private property in the Greek territory are laws 2308/1995, 2508/1997, 2664/1998 and 3127/2003. The laws described below concern the registration of private property in a broader context and they are provided by the Greek legislation:

– "superficies solo credit" in the Roman law, whatever is positioned above or below the surface of the earth (with the exception of some mines), belongs to the holder of the related land-parcel thus, the ownership of a part of land normally incorporates all the constructions on it (article 954 C.C.).
  Exceptions to the "superficies solo credit" principle establish:
– Law 3741/1929 (article 1002 C.C) "about ownership per floors", which has determined the fundamental principles of the "horizontal ownership", as well as Law about "Mines' ownership".
– Article 1010 C.C concerning building party on an outland real estate
– Articles 1118-1141 of the C.C. Land interests, such as various servitudes, provide the benefit of holding a part of foreign land (e.g. right of way, sewers, etc.).
– Customary law, which applies to several Aegean islands, controls legal relations on ownership rights, such as joint properties, implantation privileges, constructions on foreign parcels, etc. Special Real Property Objects we described above apply in this case as well.

It is quite obvious that Greek legislation contains contradictory laws on property rights, which is rather confusing; therefore there is a need to perform relevant reforms and adjustments in order to tackle this situation. A primary arrangement would be to repeal old laws such as (superficies solo credit) Article 954 of the Civil Code, while reviewing and redefine those applied to comprise the description of three-dimensional objects.
Besides, after a comparative review of all countries' questionnaires concerning 3D Cadastre, we realize what the main deficiencies of the country's legislative framework are regarding the registration of 3D objects:

- There is no generic or specific legislation (laws or regulations) stipulating the three-dimensional description of objects, even in a 2D way.
- There is no specific legislation describing the specifications for surveying plans in 3D, even in 2D. On the other hand, the Dodecanese's Cadastre provides floor plans per floor of property, in addition to the cadastral plans of land parcels, thus we know in situations where horizontal ownership hasn't been established, which part of the three-dimensional object belongs to whom. Consequently, we have a clear view of the allocation of rights in the vertical component.

7. CONCLUSIONS

Finally, the transition to a three-dimensional cadastral model requires further study and knowledge of the current model, since it's vital in considering fundamental issues of the operating HC, such as the fact that the outlines of any construction are not represented on the cadastral map. Another issue we need to consider is the cost of this transition, which would be quite large, thus we ought to be careful and precise when planning and designing the new model. In any case, it is necessary to make a cost-effective analysis in advance. We presented the characteristic cases, which require 3D registration, and we concluded that the hybrid model seems to be the best solution for the Greek case. Besides, after some 3D cases we modified in Arcscene and the 3D visualization, we realized that the ownership status of even the most complex properties becomes comprehensible.

The key issue and main drawback concerning the development of the Greek Cadastre is that it is basically legal, therefore the limitations do not stem from the weaknesses of the producers and users of the cadastral system nor from the expertise they have developed, but from the insufficiency and inactivity of the existing structures of the public administration to adapt to new data and new global tendencies and, of course, their relactance in supporting the scientific personnel of HC in order to enhance numerous aspects of the Greek reality.

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