CadaSPACE: A Cloud Based Platform for a low - cost 3D visualization of property rights available in a 2D cadastral registry. An example for urban multi – storey buildings

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Abstract

This paper presents a methodology for a low – cost 3D visualization of property rights in multi – storey urban buildings using available and other relevant open geometric and legal data. An online, free platform is created, named "CadaSPACE", to support the homogenous visualization of volumetric property units and open property rights included in 2D cadaster. The platform is directly interconnected with open – access pages such as the National Cadastral Portal, Autodesk Online Viewer, Tandem, Google Earth and Online 3D Viewer. It offers a wide range of statistical tools such as tables and diagrams to present, filter and manage the sematic information of the 3D property volumes. An application is presented for the Greek Cadaster. Legal information about the property rights is collected from the open - access cadastral records; building footprints are digitized on the available Orthophotos; architectural floor plans of each individual property unit are either taken from the documents included in the electronic building identity records (under construction) or are provided by the owners, and an approximate BIM (Building Information Model) is created for each building using additional approximate geometric information derived from Google Earth Pro and Streetview. The 3D property units are modelled and visualized as volumes. The whole 3D neighborhood model is uploaded online for further categorization and management through various visual and semantic filters. Considerations for further legal and technical improvements are given towards the implementation of the proposed methodology.

1. Introduction

The 3D visualization of urban legal rights and spaces can better support the operation of property markets and can provide useful information for the management of urban spaces. It can also support a gradual transformation of traditional 2D cadastral and property registration systems into dynamic 3D volumetric entities. BIM technology can serve as the means to 3D property rights visualization and representation as it entails many tools that allow the 3D delineation of geometric boundaries. BIM also favors storing important semantic information. In this way cadastral, semantic and geometrical data may accompany each 3D legal volumetric space. Nowadays open standards and cloud – based procedures have been established. Cadastral registration portals can operate by utilizing available and open data while disposing their stored information to citizens in one homogenous, accessible and free – to – use digital environment. Experts, professionals and authorities can supervise and control the operation of such platforms in order to preserve the balance between sensitive information and openly available data. Citizen participation in cadastral, property registration, land management and planning procedures is important. Residents have the needed knowledge of the geospatial layout, legal distinctions and daily problems of their neighborhood thus being able to participate in cadastral, land registration and other land management incentives. Inclusivity, openness and transparency in the cadastral registration actions support security of land tenure which leads to the shrinkage of social and fiscal discriminations.

The proposed paper suggests a cloud – based and publicly available platform named "CadaSPACE" that combines necessary information and technologies for performing a low – cost 3D property right representation by utilizing open data from the Official National Cadastral Records and other platforms, favoring citizens and professionals to utilize it in the future. The proposed platform also merges the 3D visualization of property rights with thorough cadastral and semantic information. The constructed platform also provides the 2D footprints of the buildings as well as statistical information about the entailed property units. By providing all the above-mentioned data in one seamless virtual and open environment, a step towards 3D Cadastre is made. By visualizing the various property units as volumetric prisms, the cadastral and legal information is represented in a more clear, interactive and comprehensive manner. Platforms like "CadaSPACE" could empower legal rights and personal ownership. "CadaSPACE" could be useful for citizens as it provides the possibility to visualize both property boundaries and legal rights online. It could also aid real estate professionals such as engineers, notaries, real estate brokers, land surveyors, constructors, etc. In the future, the platform could be accordingly modified in order to enable the engagement of professionals. Professionals could add specified information about the volumetric property units such as land value, legal documents official survey plans, etc.

Land administration has to do with the management of all the legal and spatial information that are correlated to the land (Balla et al., 2022). The complex and dense urban infrastructures of today demand a proper legal registration of their properties and status which the existing 2D cadastral registries cannot thoroughly complete (van Oosterom, 2013). The contribution of 3D spatial information models in land administration practices in complex multi – storey constructions is significant (Rajabifard et al., 2018). Therefore, applications and frameworks for property registration and land management purposes centered around BIM technology have been vital for many years. For example, BIM has been studied as a means of volumetric representation of ownership boundaries (Atazadeh et al., 2017). The combination of BIM and GIS standardizations

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can play a vital role in public administration and 3D cadastral procedures. (Janecka, 2019). A proposal of seamlessly integrating BIM and GIS technologies has been researched as an academic course providing methods for common spatial applications (Hijazi et al., 2018). An applicable case study has taken place in Sweden which proves the importance of mixing cadastral data with BIM and GIS technologies (Sun et al., 2019). A solution which merges BIM and IFC (Industry Foundation Class) data with a conceptual cadastral database according to LADM (Land Administration Domain Model ISO 19152) and national standards in one open platform, has also been created (Andritsou et al., 2022). A model of the MVD (Model View Definition) standard has been structured based on the technical demands of the IDM (Information Delivery Manual ISO 2948) for a quicker 3D land registration process while it contributes to an easier creation and distribution of topographical boundaries (Oldfield et al., 2017). A BIM – 3D GIS empowered cadastral system has also been researched in order to be distributed in Morocco by utilizing CityGML and IFC standards for the 3D presentation of cadastral entities (Hajji et al., 2021).

In New Zealand a paradigm for a 3D cadastral transition has been made while suggesting the presentation of 3D parcels as spatial objects (Gulliver et al., 2017). In Greece crowdsourced cadastral methods have been developed and implemented such as the creation of two web – based applications that can support the functionality of the official cadaster in property rights declaration processes (Mourafetis and Potsiou, 2020). BIM – based crowdsourcing methods have been developed and studied. A project has been developed that aspires to reduce energy expenditure in buildings by managing the different phases of renovative works while collecting and storing crowdsourced information from residents of a building in one cloud – based platform (Rezvani et al., 2021). Tested technical solutions have been proposed that suggest the implementation of newly constructed large buildings to 3D crowdsourced cadastral surveys (Gkeli et al., 2021). BIM may host information that is crucial for cadastral and public – enabling applications. Appropriate standardization extensions have been proposed for enabling ownership and property boundary information inside the BIM files (Atazadeh et al., 2017). Queries have also been developed for extracting information on the type of ownership that characterizes a 3D property (Atazadeh et al., 2019). Platforms for collecting adequate geometrical and semantic data to construct 3D building models have also been distributed, aiming to be utilized by the public (Zhang et al., 2021). Analytic tools and interactive visualization technologies can aid the urban planners to spot differences as well as similarities between the built environment and the planning guidelines (Dalmau et al., 2014). Modernized 3D cadastral systems could also implement 3D information and data about underground entities and cover these complex ownership situations too. A proposal on that topic which uses indoor – mapping methods has been created (Kim et al., 2015).

2. Methodology

2.1 Overview of the proposed methodology

The presented methodology is centred around creating BIMs of neighbourhoods and modelling the individual property units in multi – storey buildings as 3D volumetric prisms according to the available documentation that can be found in the Official National Cadastral Portal. The modelling phase of BIMs and 3D legal spaces is primarily based upon the availability of architectural, topographical and floor plans.

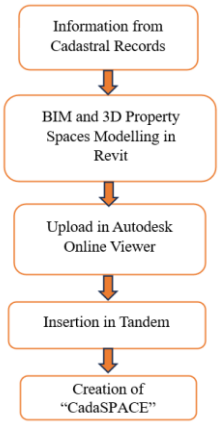

Figure 1. The 5 phases of creating the proposed 3D cloud - based cadastral registry.

The suggested methodology is comprised of 5 main phases (Figure 1): (a) obtain the legal and area size information about each property unit from the Official National Cadastral Portal, (b) model all BIMs of the neighborhood under study, connecting the individual property units (as 3D volumetric prisms) with the cadastral information in Revit by Autodesk, (c) upload the 3D models in the online visualization platform of Autodesk Online Viewer for communicative display and interaction, (d) insert the BIMs in the cloud – based platform of Tandem by Autodesk for thematical representation and classification of the 3D property spaces, (e) composition of the "CadaSPACE" platform utilizing the ArcGIS Online program by ESRI. The entire methodology presents a proposed example for 3D cadastral registrations in Greece.

2.2 Obtaining Information from the Cadastral Records

A prerequisite for this methodology is the open access to cadastral data. The Official National Cadastral Portal should be fully accessed by experts and professionals such as engineers, attorneys, etc. Citizens may have full and free access only to their own rights and properties. Property tracking is made by the coordinates. Using the National Cadaster Code Number (unique for each property unit) as the primary key (Figure 2), the user can have access to all relevant files.

Figure 2. Searching using the National Cadastre Code Number.

In the 2D cadastral records there are separate files for each legal property unit in multi – storey building. Each file includes information about: the parcel (Table 1), the property (Table 2) and the right holder (Table 3) as it is presented in the following tables.

Parcel	Address	Postal Code	Municipality Name

Table 1. Information regarding the parcel

Property	Type, Floor and Area Size	Shared Ownership‰ on the Parcel	Ownership and Shared ownership (if it exists) on the property unit

Table 2. Information regarding the property

Right Holder	Type of Ownership and Ownership Rates	Ownership of additional properties

Table 3. Information regarding the right holder

The information about: (a) type and name of the property, (b) floor that it is placed, (c) shared ownership ‰ on the parcel, (d) ownership and the name of the right holder, (e) the existence of additional ownerships.

2.3 Modelling of the BIMs and the 3D Property Units

Figure 3. The completed BIMs of the area under study.

For the construction of the BIMs (Figure 3) the following information is used: (a) architectural and floor plans (derived either from the electronic identity record of the building or provided by the owner), (b) building footprint digitized on the orthophoto of the cadastre, (c) approximate elevation information on the ground and measurements on the facades derived from Google Earth Pro, (d) texture information and information about the surrounding area (parking ramps, fences, cars, playgrounds, pathways, trash bins, benches, bushes and trees) (Figure 4).

Figure 4. Constructed, daily - life and vegetation elements such as fences, playground, cars and vegetation.

BIM serves as the basis for the representation of the 3D property units. The property areas are modelled as 3D volumes following the boundaries of the 2D plans. The 3D volumes of each property unit are created by utilizing the geometric information and structural layout depicted in the 2D plans. Information about the elevation can derive either accurately from the official height diagrams or vertical profiles or approximately from Google Earth Pro. The modelling of the boundaries of the 3D property units follows the Greek legislation. The boundaries between a privately owned property and a commonly owned one, are set on the external walls of the private property. The boundaries between two private properties are set on the middle of the common wall. For each 3D property volumetric prism that is created, important semantic information from the cadastral records is also registered.

2.4 Uploading the BIMs in the Autodesk Online Viewer

Autodesk Online Viewer is a cloud – based platform that enables easy, fast and free – of – charge display and exchange of many Autodesk products between various stakeholders and users under one communicative virtual hub. The BIM of the area under study is uploaded in the aforementioned platform, making it visible for other users in the browser. The platform preserves the textures and materials that are applied in the Revit Software making it possible for other viewers to get a grasp of the real approximate appearance of the models. Amongst other functionalities, this Online Viewer allows performing measurements on the facades and the architectural elements of the model (Figure 5).

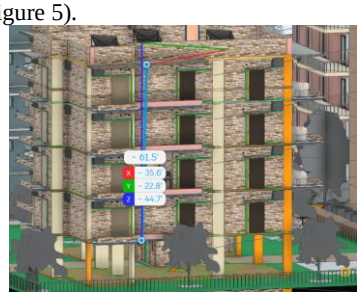

Figure 5. Measurements on the facade of a building.

2.5 Inserting BIMs and Property Volumes in Tandem

In the cloud – based platform of Tandem the 3D property units are depicted as volumetric prisms that can be categorized according to the cadastral classification. The prisms can be selected, managed, displayed, edited and viewed. The size of each volumetric property unit is defined according to the architectural floor plans and is accompanied by the cadastral information (Figure 6).

Figure 6. Example of visualization of a volumetric property.

The multi – storey buildings may contain multiple types of legal property units such as: (a) Storage Rooms, (b) Underground Parking Spots, (c) Open Parking Places and (d) Apartments. There may be on each property volume and also shared ownership rights ‰ on the land parcel. The volumetric prisms are presented, firstly, according to their “Type” (Figure 7).

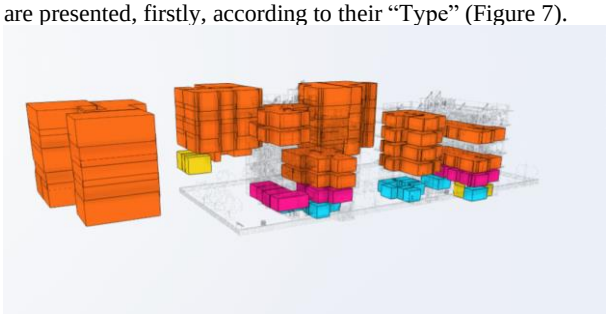

Figure 7. The 3D properties visually classified by Type.

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Property units that belong to the same right holder (Figure 8) may have the same color or alternatively property units of the same type may have the same color. In this way the prisms are presented in different color groups while the according semantic inventories are also categorized. By example, Table 4 presents the different colourations that are chosen for each "Type" of the 3D property prisms.

Apartments	Parking Places	Storage Rooms	Underground Parking Spots
Orange	Pink	Cyan	Yellow

Table 4. The different colours of each property type category.

Figure 8. The 3D spaces filtered by right holder.

Figure 9 shows a selected volumetric prism with accompanied cadastral information.

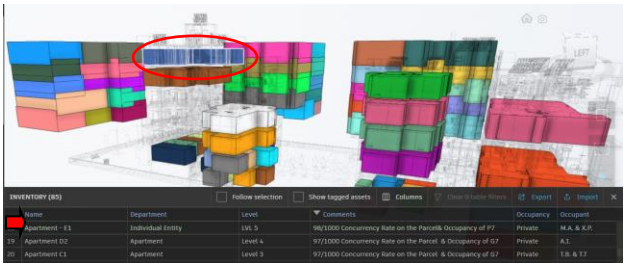

Figure 9. The selected Apartment E1 (in red circle).

Figure 10 shows all the apartments, Figure 11 shows all storage rooms and underground parking spots and Figure 12 shows all the open parking places.

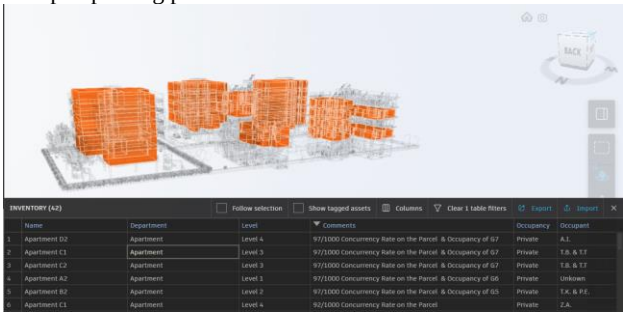

Figure 10. Apartments.

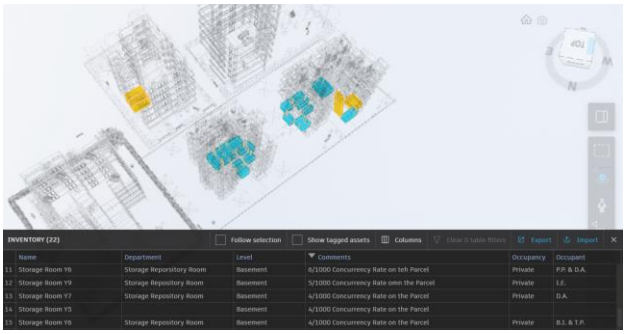

Figure 11. Storage Rooms and Underground Parking Spots.

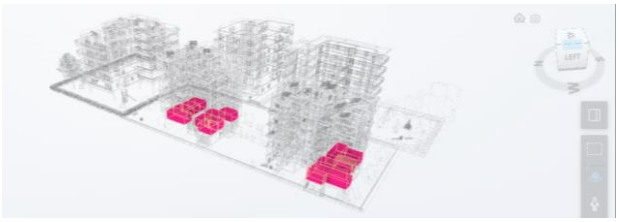

Figure 12. Open Parking Places.

3. Structure of the Platform

The "CadaSPACE" platform is constructed by utilizing the mapping and spatial analysis software ArcGIS Online by ESRI which operates like an online service. ArcGIS Online serves as an online community for mapping, digitizing, creating and managing 2D and 3D geospatial data.

More specifically, "CadaSPACE" is crafted utilizing the Experience Builder Application which is also free – to – use and access to it is granted alongside any public, academic or paid license for ArcGIS Online. Experience Builder is a highly modular and customizable virtual environment that gives the users the opportunity to create their own internet page or platform by using a wide range of widgets and operations.

The proposed platform of "CadaSPACE" is created under an academic account which is free – of – charge like all the other non – commercial and public account types. So, the proposed platform can be accessed by anyone once it is made "public".

Figure 13. The "CadaSPACE" logo. The orange arrow represents the data search, the green boarder displays 2D data, the line is the transformation process and the yellow rhombus concerns 3D data.

"CadaSPACE" is structured around 4 different "Sections" that serve distinct purposes and contain unique tools (Figure 13). "CadaSPACE" is created in order to enable future citizen participation towards a 3D cadastral registration through a cloud – operated and low – cost way. The tools used are redirect buttons, embedded pages, semantic tables, statistical diagrams and graphs.

The redirect buttons are actually pop – up frames that entail an internet address in URL format. Once a button is clicked then the designated page, platform or online program is seamlessly triggered and quickly accessed in a new browser window while being fully explorable (Figure 14). CadaSPACE is connected, in this way, with the official page of the National Cadastral Records as it is shown in Figure 15.

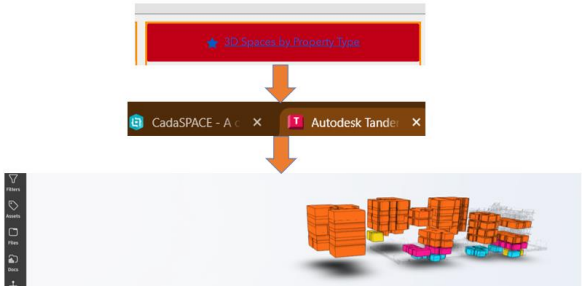

Figure 14. The access procedure of an online platform through "CadaSPACE".

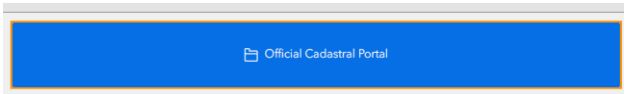

Figure 15. "Official Cadastral Portal" interactive button.

"CadaSPACE" is themed around the simultaneous and combined disposal of 3D property models and semantic cadastral information. A table can be handily incorporated in the "CadaSPACE" interface thus providing the needed cadastral and semantic information on each 3D legal property unit. The contents of the table can be viewed, managed and filtered while statistical graphs and diagrams can be produced based on them.

The registration table plays an important role to the entire methodology as it is the link between the 3D and the 2D representation of the property units. Figure 16 shows information about each 3D property unit of every modelled building such as: (a) the building address, (b) property type, (c) floor, (d) shared ownership ‰ on the land parcel, (e) ownership, (f) name of the right holder, (g) export type to IFC, (h) if the property unit has an open parking place or not and (l) if the same right holder occupies more properties.

C1	Apartment	Level 3	92/1000	Private	Z.A.
D1	Apartment	Level 4	92/1000	Private	P.S.A.
Y1	Storage Room	Basement	9/1000	Private	M.A.
A2	Apartment	Level 1	88/1000	Private	A.G.
E1	Apartment	Level 5	85/1000	Private	P.P. &
B2	Apartment	Level 2	81/1000	Private	K.S. &
C2	Apartment	Level 3	81/1000	Private	I.P.
E2	Apartment	Level 5	81/1000	Private	M.P. &
Y2	Storage Room	Basement	8/1000	Private	R.P. &
Y3	Storage Room	Basement	8/1000	Private	K.P. &

Z.A.	Apartment	IfcSpace	No	No	
P.S.A.	Apartment	IfcSpace	No	Parking Spot Y1	
M.A. & X.P.	Storage Repository Room	IfcSpace	No	Apartment E1	
A.G.	Apartment	IfcSpace	No	No	
P.P. & P.B.	Apartment	IfcSpace	No	No	
K.S. & M.T.	Apartment	IfcSpace	No	No	
I.P.	Apartment	IfcSpace	No	No	
M.P. & M.O.	Apartment	IfcSpace	No	No	
R.P. & R.M.	Storage Repository Room	IfcSpace	No	Apartment B2	
K.P. & K.E.	Storage Repository Room	IfcSpace	No	Apartment B1	

Figure 16. An example of the E1 Apartment in the table.

Figure 17 shows a filter that searches and presents information about the apartments.

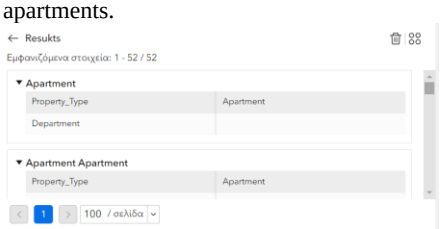

Figure 17. Apartment filter

Four unique statistical diagrams and graphs have been created, utilizing the fields of the inserted table "3D Property Spaces Semantic and Occupancy Registry" as the data basis. The diagrams and graphs offer a statistical and mathematical analysis of the data. Figure 18 shows a "pie" diagram of the percentage of each different property type in the area under study. As it is shown the majority of the legal properties are apartments (56%). The underground parking spots represent the lowest percentage (2%).

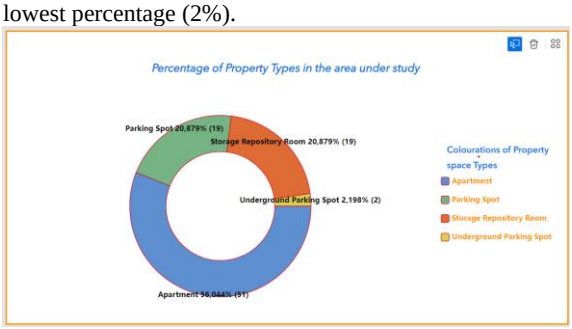

Figure 18. Pie diagram.

Figure 19 shows a "bar" diagram for the open parking places. As it is showed 59 property units do not have an open parking place while 16 property units have an open parking space.

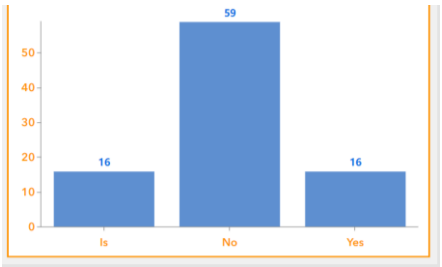

Figure 19. Bar graph.

Section 1 of the platform has all the needed tools and buttons for obtaining official legal and geometrical information from the cadastral records, modelling the BIMs, viewing them online and visualizing through various types of filters the property volumes (Figure 20).

Figure 20. Section 1 of "CadaSPACE".

Figure 21 presents the cadastral and semantic information of the 3D volumetric property units. This section consists also of the filter tool for the cadastral data of the 3D property units.

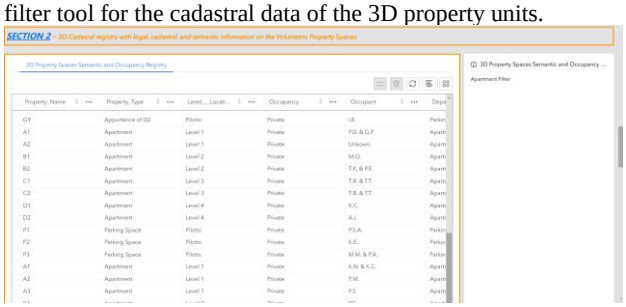

Figure 21. Section 2.

Section 3 consists of the interactive 2D map with the building footprints, the Google Earth Extension and the embedded "Online 3D Viewer" page (Figure 22).

Figure 22. Section 3 of "CadaSPACE".

Section 4 (Figure 23) has to do with the statistical analyses of the fields of the registry. It presents the "pie" and "bar" graphs.

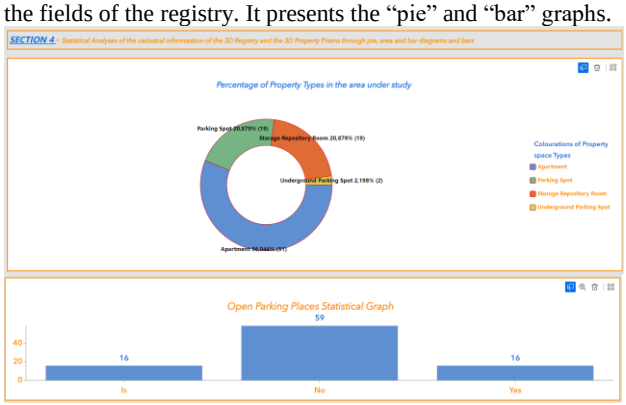

Figure 23. Section 4 of the proposed platform.

4. Conclusions

4.1 Final thoughts on the proposed methodology

The presented platform is free – to -use and cloud - based making it possible in the future to support 3D crowdsourced cadastral registration. "CadaSPACE" platform enables a low – cost solution for cadastral registration as all the utilized tools and software that are embedded in it are free – of – charge (Table 5).

National Cadastral Portal	Autodesk Online Viewer	Tandem by Autodesk	3D Online Viewer	Google Earth
No Cost	No Cost	No Cost	No Cost	No Cost

Table 5. The embedded platforms in "CadaSPACE" are free of charge

The platform is an all – in – one virtual environment for observing, modelling, visualizing, classifying, managing and analysing 3D property units. "CadaSPACE" integrates seamlessly official portals, online pages and platforms granting the user immediate and easy access to them. "CadaSPACE" combines 2D and 3D data as well as documentation with modelling.

"CadaSPACE" promotes the importance of open official data, information exchange and cooperative procedures. It may be used to increase transparency in land management and planning, accompany crowdsourced methods in the future and minimize land disputes.

Two – dimensional plans and data are not adequate enough to visualize the complex legal situations of urban properties as they fail to depict intertwining or superimposed properties. "CadaSPACE" could aid reforming the current 2D cadastral procedures as it offers a graphic 3D environment and volumetric presentation of property unis and legal rights by utilizing 2D plans as the geometrical basis for creating BIMs.

The outcome of the proposed methodology is an openly accessed platform for seamless and communicative 3D property unit registration while incorporating various important semantic and statistical data.

4.2 Discussions and suggestions for future improvements

The proposed methodology suggests a low – cost procedure on creating approximate BIMs of existing multi – storey urban buildings by utilizing available plans and open portals such as the official Orthophotos and Google Earth Pro. Approximate BIMs of the existing buildings can be created by: (a) delineating the building footprints on the Orthophotos, (b) acquiring the ground elevation from the open platform of Google Earth Pro, (c) conducting horizontal and vertical measurements on the facades in Google Earth Pro and (d) adding information about the textures of the architectural elements from the open platform of Streetview.

By integrating such individual approximate BIMs with BIMs of the new constructions in an urban area, a low - cost 3D geospatial infrastructure can be created which may be used for:
(a) a crowdsourced 3D cadastral registration where right holders will be able to identify their property unit and insert the cadastral code number. A future step of this research will enable an automatic linkage with the cadastral records.

(b) the creation of Digital Twins of urban neighbourhoods that can be used for a number of applications such as monitoring, environmental projects, land use planning, disaster management and other services within the spectrum of digital governance.

The abovementioned methodology is adequate and satisfactory for the purposes of creating fast and low – cost approximate BIMs of neighbourhoods. It is also an easy procedure for constructing a 3D Cadastre with available information as the architectural floor plans can be either provided by the right holders or be available through the electronic building identity (especially for new constructions).

As a future suggestion, the proposed methodology can be properly extended for enabling a crowdsourced 3D cadastral registration process of property units in multi – storey urban buildings. The proposed platform can be accordingly modified in order to be able to host citizen participation methods. Greek

citizens are already familiar with 2D crowdsourced cadastral registration procedures as this is an option for an electronic submission of declarations of property rights and digitization of land parcels by the right holders during the official national cadastral survey. Therefore, it is anticipated that it will be easy to adjust a 3D crowdsourced cadastral registration following a brief demo.

The approximate BIMs of the existing buildings can be integrated with BIMs constructed for the new buildings and can provide geospatial infrastructure to be used as a 3D cadastral basemap, enabling a simultaneous view of the 3D models and the open – access official 2D cadastral maps. The cadastral code number of the selected property unit, by the right holder, can be the linkage between the 2D cadastral information and the BIMs. By utilizing the available architectural plans and the open legal and cadastral data information found in the cadastral records, the right holders will be able to identify their property units in the 3D models. In one homogenous virtual environment the 3D property units, the 2D land parcels and the BIM of the neighbourhood will be available. The 3D property units will be enriched with cadastral and legal information found in the records. Special attention should be paid so that legislation about protection of sensitive personal data will be enforced in a similar manner as it is currently enforced for 2D legal cadastral data.

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