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# A BIM/IFC – LADM SOLUTION ALIGNED TO THE GREEK LEGISLATION

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**ABSTRACT:**

The ongoing rapid urbanization has led to the emerge of several complex infrastructures distinguished by multi-dimensional and overlapping property rights. The option of integrating BIM data into LA, aligned with international standards and able to handle the three-dimensional (3D) aspect of cadastral objects utilizing contemporary technologies, may be of a great importance. The main objective of this paper is to investigate the potential integration of the Building Information Model (BIM) and the Industry Foundation Classes (IFC) standard, with the international standard of Land Administration Domain Model (LADM ISO 19152 2012), in order to provide a unified solution for the registration and visualization of 3D spatial and sematic information regarding the complex Rights, Restrictions and Responsibilities (RRR) in the new complex constructions. The proposed solution aims to exploit the available 2D plans for the generation of BIMs; and rely on international LADM's constructional guidelines to provide a standardized cadastral database harmonized with the national Greek cadastral and the legal framework and aligned with the current Greek building code. The proposed framework is tested for two multi-storey buildings. The first results are promising constituting an important tool, for the implementation of 3D cadastres.

## 1. INTRODUCTION

For the past decades, the urban construction development has shifted its orientation to the vertical axis. This is due the expansionary phenomenon of urbanization. The urban centres contain multi-owned buildings, complex multi-story apartments, various over/ underground public systems and functional services that generate several overlapping property RRRs. Thus, private, public and common properties create an extremely complex legal environment that is exceptionally challenging to capture, both semantically and visually. 2D conventional cadastral systems, 2D plans and cross-section diagrams are not sufficient enough to represent ownerships with irregular shapes or with an extend that expands in multiple levels/stories of a building. They also struggle to properly record superimposed properties in high-rise buildings and fail to comprehend legal boundaries defined by architectural elements (Rajabifard et al., 2019).

The modern Greek urban and rural environments are being characterized by overlapping private property rights, misinterpreted boundaries between properties, the unconventional development of properties within the boundaries of a parcel, the clash of private and public interests etc. The Greek cadastral context is also defined by some distinct legal entities and spaces, such as castle cities, ancient/ traditional settlements, elevated or lowered ground floors, tunnels and under-cutting. The Greek cadastral system, does not include yet the 3rd dimension either as a legal nor as a spatial parameter, both in the land administration and cadastral registration processes. In the future, it is aimed to entail an interactive and fully implemented 3D virtual platform that enables both visual and conceptual display of complex RRRs, at the citizen's free disposal.

The implementation of BIM technology in cadastral systems and its combination with a sematic data model, currently consist one of the most investigated subject in the cadastral and land administration field. BIM accurate geometric and volumetric representation of its real counterpart has become extremely popular worldwide due to IFC interoperability and open standardization. BIM has been studied as a mean of registration and visualisation of 3D cadastral information (El – Mekawy et al., 2015; Andrianesi et al., 2020) and most specifically as an extraction and analysis tool. Also BIM importance as a 3D data provider for 3D Cadastres has been analysed (Oldfield et al., 2016), whereas categorization of IFC various legal spaces was expanded. The introduction of BIM and IFC to managing legal entities in multi – storey buildings has been scientifically established (Atazadeh et al., 2017). A possible extension of the basic IFC schema for enabling IFC-based urban land administration and changing the conventional 2D methodologies, has also been reviewed (Rajabifard et al., 2019). BIM has been further combined with crowdsourced tools for the purposes of creating a cost-effective and fast 3D cadastral registration platform (Barzegar et al., 2021; Gkeli et al., 2021).

The main purpose of the proposed solution, is the creation of a semantically enriched cadastral database, including the 3D volumetric representations of the legal RRRs, as complied with the Greek legislation. By utilizing the international standard of LADM (ISO 19152,2012), for the formulation and disposal of cadastral information; the open standard of communicating 3D building visualization (BIM) (BuildingSMART, 2021); and, the widely used IFC standard (ISO 16739 2013), a methodology for the creation of a 3D volumetric and conceptual cadastral record, in line not only with national but also with international frameworks, is developed and presented. The goal is, also, to

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give prominence to the usage of 2D survey and subdivision plans, cross-sections and diagrams as the modelling basis of complex BIMs. Consequently, the proposal is a simulation of a 3D cadastral registration process combining both spatial volumetric representations of multi-story building's ownerships (BIM) and schematic storage of the respective legal entities (LADM).

In Section 2, the main stages of the proposed methodology are described. Section 3, presents the conducted practical experiment and includes information and results concerning each phase of the implementation test of the proposed methodology for the two multi-story buildings in Chalandri, Athens, Greece. Finally, in Section 4, the main conclusion referring to this work are presented.

## 2. METHODOLOGY

### 2.1 Overview

In the following graphic diagram (Figure 1), the various individual steps that are followed for each stage of the technical execution are presented.

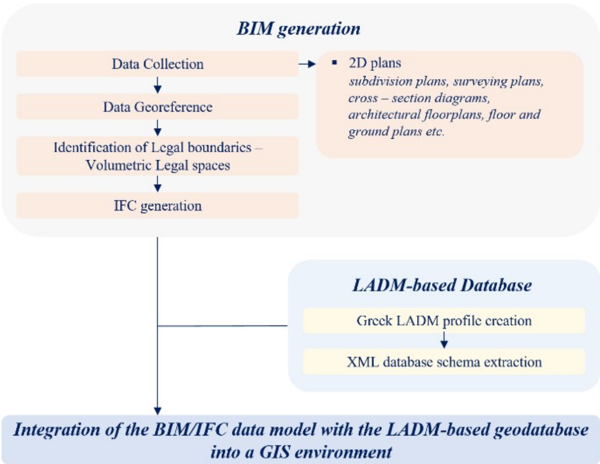


Figure 1. Overview of the proposed methodology

The technical procedure is divided into 3 major stages that are comprised of many different actions. These 3 main stages are: (a) the generation of the BIM model, (b) the creation of a LADM-based database that is in accordance with the Greek legislation, and (c) their integration into a homogenous GIS environment, through the IFC standard.

### 2.2 BIM generation process

At the first phase, all the available 2D plans and diagrams, presenting the geometrical, architectural and topological structural elements of the buildings under study are gathered to lead to the 3D modelling procedure for the generation of the respective BIMs. Consequently, a variety of 2D plans is collected from the official authorities. The collected plans include surveying, floor and ground plans, architectural floorplans and cross-section diagrams. Next, the georeference of the current plans is conducted, in AutoCAD environment. Through the conduction of field surveys the necessary geodetic and elevation measurements are obtained to complete the georeferencing process. The 3D modelling phase of the BIM followed, in which all the architectural structural, functional and textural details of the real counterparts are preserved. The various legal spaces, private and common, of the studied construction are identified and depicted in the 3rd dimension as RRR areas, in full accordance with the Greek cadastral legislation. The final step of this stage entails the export of the BIM into the open and interoperable format of IFC.

### 2.3 LADM-based Database creation

The database is created according to the Greek legal and cadastral framework, following the structure of the global standard LADM (ISO 19152,2012). The database contains classes that represent the entities that interest the Greek law, while the same goes for the properties and features of the classes. The conformation of the database schema abides to the standardization of LADM. It entails a variety of object classes that relate and connect with each other through different types of relationships and associations, that succeed in the creating of a constant flow of information. Finally, the database is extracted in a XML format.

### 2.4 Integration of BIM/IFC and LADM models into GIS

For the needs of creating a unified and complete virtual cadastral environment that entails both spatial and schematic representation of the modelled RRR spaces, a GIS platform of ArcGIS Pro is utilized. The GIS incorporates the volumetric presentation of the modelled buildings, through the IFC standard, enabling the volumetric representation of the legal RRRs of the properties. It also combines the conceptual side of the proposed cadastral registration, through the XML format of the database. That way, the user has access to the necessary data that refer to a certain owner, right, restriction or responsibility while observing the properties of the 3D volumetric model.

## 3. PRACTICAL APPLICATION

In this chapter, a practical application of the proposed methodology is presented. Each one of the implementation phases is explained and tested. The technical application is divided into 5 main stages.

### 3.1 Study Area

The study area includes two (2) urban blocks, in the municipality of Chalandri in the distinct of Attiki, Athens in Greece (Figure 2).


Figure 2. The two city blocks that consist the study area (696a and 695)

The first urban block (Figure 2, 696a) includes three (3) land parcels. The two (2) of them include apartment buildings. The first one is a four-story apartment building (Figure 3), whereas the second is a five-story one (Figure 4). Both apartment buildings entail a pilotis, a basement and a penthouse.

Figure 3. The four-story apartment building

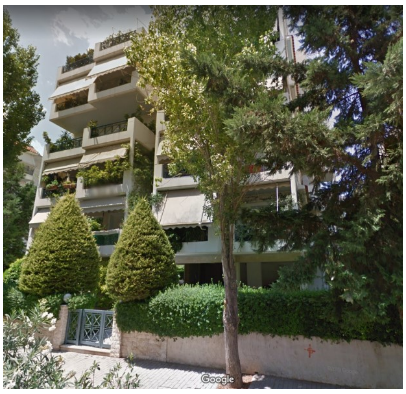

Figure 4. The five – story apartment building

The second urban block is public space and it includes a play-yard (Figure 2: 695), (Figure 5).

Figure 5. The public/common city block

Part of the study area, are also parts of the road and the sewer system in front of the studied multi-story buildings (Figure 6).

Figure 6. The researched road network, which underneath it entails the sewer system

Subsequently, the study area contains: two privatly owned apartment buildings, a public land parcel, a road and part of the sewer system.

### 3.2 Data Collection

Based on the proposed methodology, the necessary 2D plans were collected from the responsible authority. The 2D plans are the primary data used for the project. They include: ownership parcel subdivision plans, surveying plans, section diagrams, floor and ground plans and architectural floorplans. The building permits are collected from the respective archive (Figures 7, 8, 9).

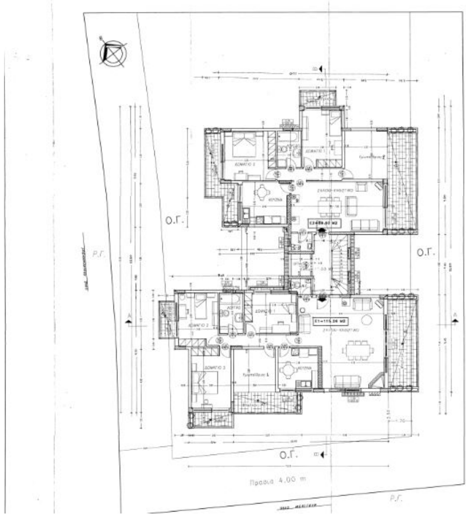

Figure 7. The floor plan of the four-storey apartment building

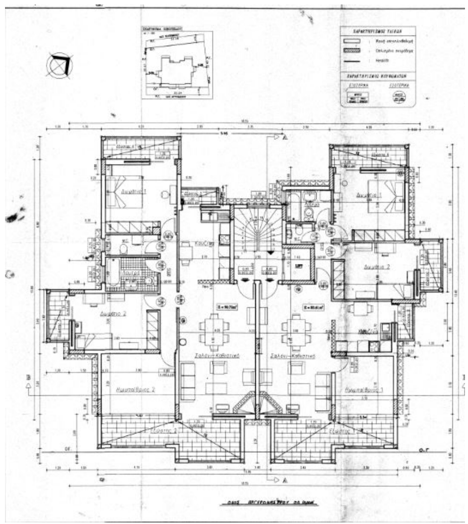

Figure 8. The floor plan of the five-story apartment building

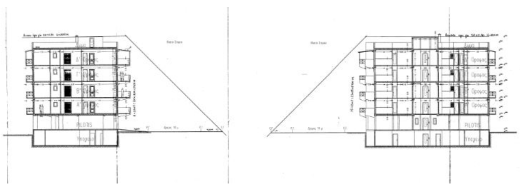

Figure 9. The cross section diagram of the two apartment buildings

The official cadastral abstract of the land parcels is obtained in virtual (vector) format from the INSPIRE portal of the National Cadaster website (Figure 10 left).

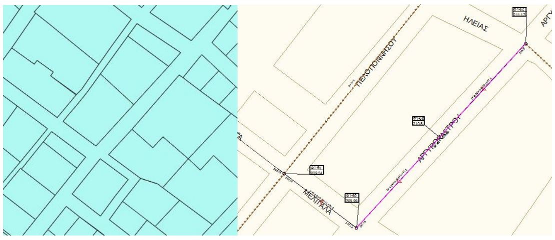

Figure 10. The official cadastral parcel boundaries of the area (left) and the sewer system plan (right)

Finally, the sewer plan is derived from the official GIS service of AWSSC (Athens Water Supply and Sewerage Company) (Figure 10 right).

### 3.3 Data Processing and Editing

The next step concerns the georeference and editing of the above mentioned 2D plans, in the environment of the AutoCAD (Figure 11).

Figure 11. A georeferenced and edited 2D floor plan

To implement the necessary technical steps, the collection of the appropriate geodetic data is a prerequisite. So, field surveying, horizontal and elevation measurements are conducted (Figure 12). All measurements are aligned to the Hellenic Geodetic Reference System Greek Grid (GGRS ’87). The measurements aim to properly adjust the model. By using the suitable measured parameters the plans are properly scaled, moved and rotated resulting to the georeference of all collected plans (Figure 13).

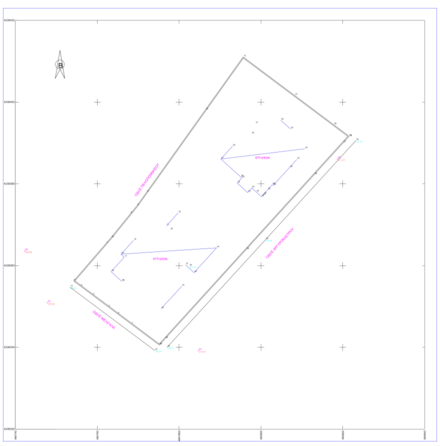

Figure 12. The geodetic measurements that derived from the field surveys

Figure 13. An orthophoto overlaid with the topographic diagram derived from the field surveys

### 3.4 BIM Creation

In this section the 3D modelling process of BIM is analysed. As mentioned above, the basis for the architectural, structural, geometric and mathematical development of the 3D models of the two apartment buildings are the 2D edited and georeferenced plans (Figure 14).

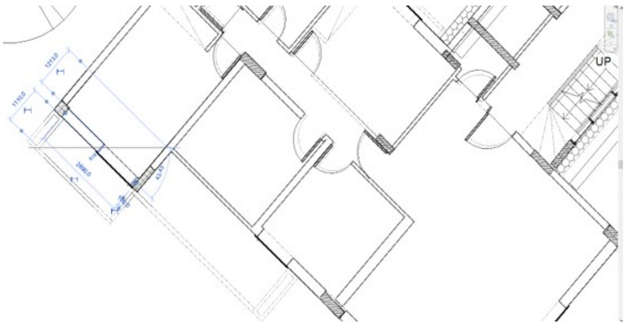

Figure 14. The inserted 2D floor plan in Revit

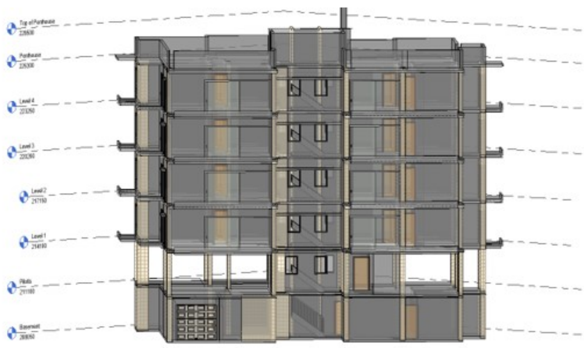

Figure 15. 3D modelling of the buildings

For the needs of the 3D virtual reconstruction of the two buildings, the Revit software by Autodesk is used. The above mentioned software offers a wide variety of 3D editing tools, accompanied with schematic recording. By creating all the necessary architectural and structural elements (floors, ceilings, walls, doors, windows, etc.), according to the plans, the two buildings are recreated in 3D format (Figure 15).
The models consist of multiple levels, apartments, exterior and interior common spaces (Figure 15). In addition to the

buildings, part of the road network and the sewer system are also modelled, while a topographic surface with vegetation is added (Figure 16).

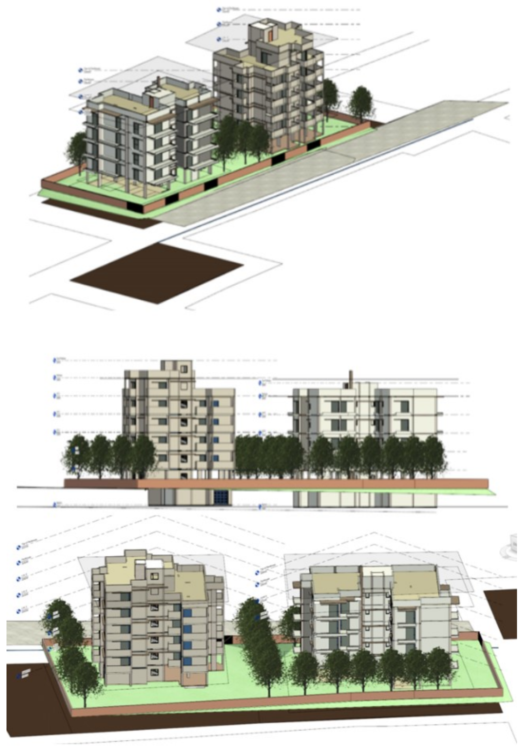

Figure 16. 3D realistic models of the two buildings

Following the thorough and extensive 3D modelling of the two buildings, the detailed spatial and cadastral recording of the various privately or commonly owned property units, is conducted. The RRRs spaces are categorized in 3 distinct sets: 1) Privately owned property units (Floor Areas), such as apartments, parking places and storage-rooms. These areas are marked in orange. 2) Commonly owned areas (Common Building Areas), such as lobbies, stairs, elevators, hallways etc. These areas are represented in azure. A variety of privately and commonly owned spaces, can be viewed in Figure 17. 3) Exterior areas (External Areas), such as the privately owned land parcels, the publicly owned land parcel of the play yard, the part of the road and sewer network. Figure 18 presents these areas in green.


Figure 17. Indicative privately (orange) and commonly (azure) owned legal spaces

Figure 18. The privately and commonly owned land parcels, the road and sewer systems

The above mentioned RRR legal spaces are modelled as 3D volumetric spaces, through the 'Area' tool, following the Greek legislation and regulations. For each set of RRR spaces, tables including some necessary semantic information are created (Figure 19). This information includes: the level, the type, the volume, the area and the perimeter of the 3D space.

| LVL | TYPE | AREA | PERIMETER | VOLUME | COMMENTS |
|---|---|---|---|---|---|
| 1 | Floor Area | 128 m$^2$ | 53243m | 358.40 m$^3$ | Apartment |

Figure 19. Example of the generated tables

Subsequently, the height and construction restrictions, that abide to the Greek building code are also modelled as 3D surfaces (Figure 20). Finally, the BIM is extracted in IFC format.

Figure 20. Height and development restrictions, as 3D surfaces

### 3.5 Presentation in Solibri Model Viewer

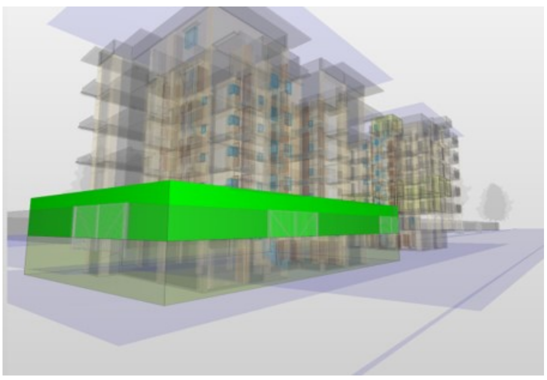

Figure 21. Volumetric representation in SMV

The BIM models are inserted into the Solibri Model Viewer (SMV) using the extracted IFC data files. A graphic volumetric and prismatic representation of the various RRR spaces that are modelled in Revit is enabled through this particular software (Figure 21).

## 3.6 Creation of the Cadastral Database

In this step, a cadastral database is created according to the international standard of LADM (ISO 19152, 2012). For the development of the database conceptual schema the Enterprise Architect (EA) UML modelling tool from Sparx Systems is used.

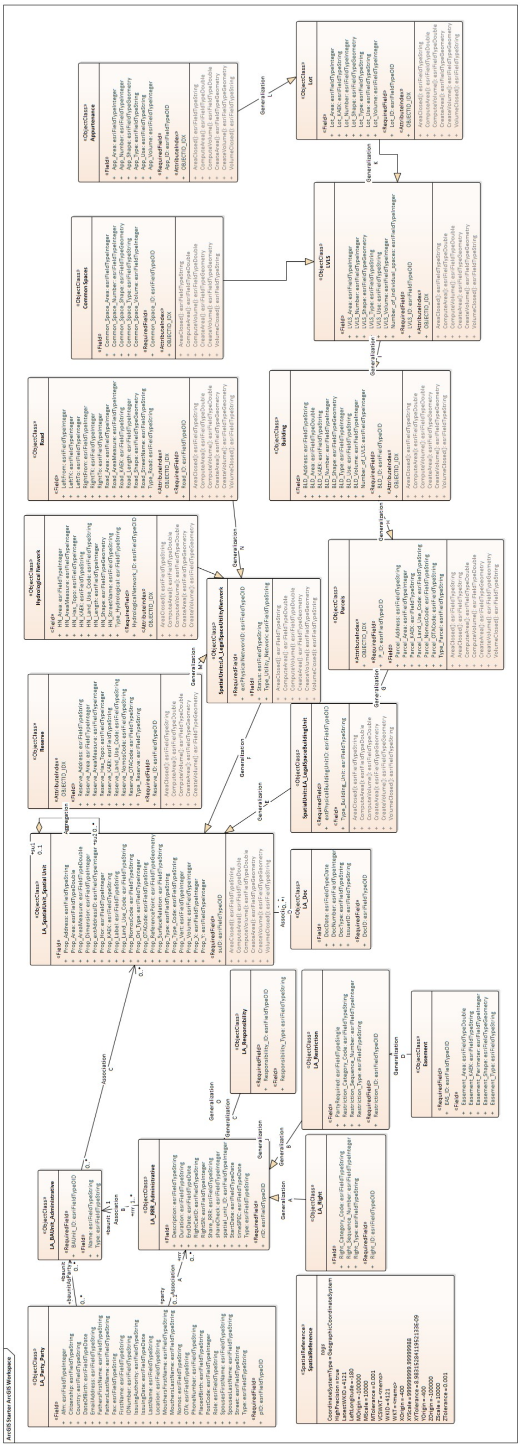

Figure 22. The schema of the cadastral database

The main classes of LADM are preserved, while some new classes are constructed following the Greek cadastral framework and legislation (Figure 22). More specifically, the basic classes of LA_Party, LA_RRR, LA_Right, LA_Restriction, LA_Responsibility, LA_Easement, LA_SpatialUnit, LA_BAUnit and LA_Doc are retained, while the specializations of 'LA_LegalSpaceBuildingUnit' and 'LA_LegalSpaceUtilityNetwork' are also included. The latter two classes are essential for linking the legal with the physical spaces, as they represent the building and the utility networks respectively.

For this particular application, a set of new classes is created. The first set contains entities concerning the built environment of the two apartment buildings. These entities refer to: (i) the parcels ('Parcels'), (ii) the two buildings ('Building'), (iii) the corresponding levels ('LVLS'), and (iv) the different types of legal spaces ('Lot', 'Appurtance' and 'Common Spaces') which are encountered in the study entities. The second set of classes includes: (i) the public networks ('Road' and 'Sewer System'), and (ii) the landscape of the studied area ('Reserve').

Each object class is enriched with a variety of attributes, according to the Greek legal framework. The attributes include information that identifies each individual class, such as the name of the owner, the address and the type of the right.

## 3.7 Integrating BIM/IFC with LADM into ArcGIS Pro

In this step, the generated BIM and the LADM data model are linked into the GIS environment of the ArcGIS Pro (Figures 23, 24). Through importing the IFC files into the ArcGIS Pro a file geodatabase is created, making the BIM physical and legal spaces available for loading into the GIS project. Besides the structural elements of the BIM, the visualization of the 3D legal spaces is also feasible, as the 'IfcSpace' entity maintains and carries this information as declared through the 'Area' tool in the Revit software.

Once the geodatabase is generated, the entities of the IFC are connected to the respective classes of the developed LADM-based geodatabase. During this process the access, the manipulation and the insertion of new semantic cadastral information is possible.

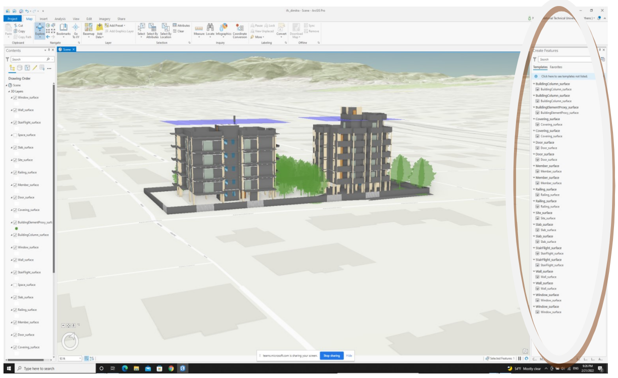

Figure 23. The combination of BIM with the cadastral database in GIS

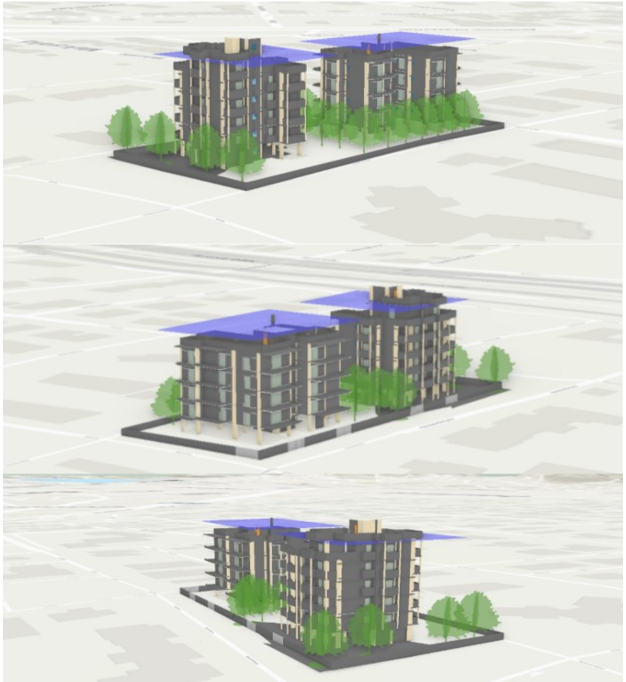

Figure 24. The final version of the proposal in GIS

## 4. CONCLUSIONS

The proposed methodology highlights the contribution of properly edited and georeferenced 2D plans in creating a complete 3D cadastral registration. Utilizing existing 2D plans (surveying plans, subdivision plans, floor and ground plans, section diagrams and architectural floorplans), a detailed volumetric 3D representation of the buildings can be achieved. 2D plans can be used for the volumetric representation of complex RRRs in a BIM, and can provide cadastral data for any cadastral database.

BIM is a rich 3D data source and a valuable tool for 3D cadastres. BIM offers a highly sophisticated and accurate geospatial registration of the complex and overlapping legal spaces and property units. The proposed technical solution proved the interoperability and flexibility of BIM, through its extraction in the open international standard of IFC format. Using open data models, BIM can be integrated into Geographic Information Systems (GIS) and enriched with additional cadastral or other information, expanding its exploitation potential in land administration. The fact that it can be combined with a conceptual database schema, such as the LADM standard, makes BIM a promising 3D cadastral tool.

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