3D Land Administration

FIG

Proceedings

11th International Workshop on the Land Administration Domain Model and 3D Land Administration

11-13 October 2023, Gävle, Sweden



Editors: Peter van Oosterom & Jesper M. Paasch

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The LADM & 3D LA Workshop is one of the activities of the LADM & 3D LA Working Group (WG), which belongs to FIG Commission 3 'Spatial Information Management' and Commission 7 'Cadastre and Land Management'. Under the responsibility of this WG two event series (the FIG LADM workshops, and the FIG 3D Cadastres workshops) are merged in the current series. Lets first reflect on the FIG 3D Cadastres workops. The 1st Workshop was organized in Delft, the Netherlands, November 2001. The 2nd Workshop was held one decade later, November 2011, again in Delft. The 3rd Workshop was organized in Shenzhen, China (October 2012). The 4th Workshop, 9-11 November 2014, was organized in Dubai, United Arab Emirates. The 5th Workshop, 18-20 October 2016 was organized in Athens, Greece. The 6th Workshop, 2-4 October 2018, was again organized in Delft, together with: 3D GeoInfo Conference, Smart Data and Smart Cities Conference, and ISPRS Commission IV Spatial Information Sciences Symposium. The 7th International Workshop on 3D Cadastres, 11-13 October 2021 was planned to be organized in New York City (USA), but due to Covid-19 was organized on-line. The history of the FIG LADM workshops is summarized in the list below:

1. March 2003, Enschede, the Netherlands;
2. December 2004, Bamberg, Germany;
3. November 2009, Quebec City, Canada;
4. July 2012, Rotterdam, the Netherlands;
5. September 2013, Kuala Lumpur, Malaysia;
6. March 2017, Delft, the Netherlands;
7. April 2018, Zagreb, Croatia;
8. October 2019, Kuala Lumpur, Malaysia;
9. June 2021, LADM & 3D LA, online (part of FIG eWW);
10. March-April 2022, Dubrovnik, Croatia

To in total 7 FIG 3D Cadastres workshops and 10 FIG LADM workshops preceed the current event. After merging the two workshop series it was decided to continue the workshop numbering from the previously highest numbered event, the LADM workshop in Dubrovink. As that was the 10th (LADM workshop), the current event is now numbered as the 11th LADM & 3D LA workshop.

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- Eva-Maria Unger (John Gitau): Social Tenure Domain Model (STDM) update
- Anders Lundquist: View from the Swedish mapping, cadastral and land registration authority

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1. Urban development / plan information LADM part 5
2. 3D legal building models/BIM
3. Legal aspects of 3D LA
4. Valuation Information / LADM part 4

The result is a very full programme as the workshop is organized as a single track for the keynotes and the regular papers and in parallel tracks for the working sessions. The on-line proceedings (papers and presentations) are available on the FIG LADM & 3D LA workshop website: http://www.gdmc.nl/3DCadastres/workshop2023/programme/.

Finally, we would like to thank all authors for their submission, the Programme Committee members for their diligent work in assessing the quality of the contributions and the Local Organizing Committee for organizing the event. We are looking forward to the 11th LADM & 3D LA Workshop and stimulating interactions in Sweden!

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Visualisation of 3D Property Units - experiences from a case study in Stockholm, Sweden

Karolina LARSSON, Sweden, Jesper M. PAASCH, Sweden/Denmark, Jenny PAULSSON, Sweden

Key words: 3D real property, property formation, 3D models, registration, visualisation, Sweden

SUMMARY

This paper focuses on experiences concerning a project aiming at visualisation of three-dimensional (3D) property units in Stockholm, Sweden. The Swedish national registration system, the national real property register, includes a textual description as well as a two-dimensional map, normally consisting of a scan of the legal map document produced during the property formation process. Today, a 3D-pdf or a BIM model cannot be part of the formal property formation decision and documentation. It can thus be difficult to illustrate 3D real property on just a two-dimensional map.

The paper describes a project carried out by Stockholm municipality to visualise 3D property unit volumes within the municipality by combining them with existing 3D city models (including building- and terrain models). The aim is to show and analyse the problems and challenges identified in the project by illustrating what has been done and how the use of 3D real property information can be further developed in the future.

The method used in this research is a document study of the project focusing on representation in the digital cadastral index map for 3D real property units as part of the national real property register, as well as associated documentation from other agencies, and by interviewing key persons involved in the project.

The project created a local 3D model which is stored in the municipality´s own internal database. Some information was retrieved from the national real property register, such as information on height (lowest and highest) and the horizontal expansion of the real property. Data was then processed and analysed using Feature Manipulation Engine (FME) to create 3D property volumes. The project used in-house software and data as much as possible. The volumes were stored in the municipal database.

The 3D volumes could be used as a supplement to the information stored in the national real property register and the cadastral dossiers. The results can be used as a component for the development of a national three-dimensional cadastral index map as well as for enabling 3D models as part of the formal cadastral property formation procedure.

Visualisation of 3D Property Units - experiences from a case study in Stockholm, Sweden

Karolina LARSSON, Sweden, Jesper M. PAASCH, Sweden/Denmark, Jenny PAULSSON, Sweden

1. INTRODUCTION

It has been possible to form 3D real property and property volumes (hereafter called 3D property units) for almost twenty years in Sweden. The number of 3D property units is increasing, even if they still are a rather small number in relation to other forms of real property. The current number of 3D objects in the national real property register is ca 5000 (LM 2023). Swedish 3D property volumes are described by two-dimensional drawings and a verbal description. These drawings may consist of or include sections of 3D models in the form of a picture or 2D drawings. All Swedish real properties are described in the national real property register. The register has a textual part and a geometrical part, where the maximal extension for 3D volumes only are described horizontally and with the highest, respectively lowest, point for the volume. This makes it difficult to obtain a vision of the volume's exact extension and form. Many actors have the need to determine the exact extension of a real property, for example property owners, building permission staff, city planners, different agencies and the building industry.

1.1 Problem description

3D property units are difficult to present in a two-dimensional map. The Swedish Cadastral Index Map is part of the national real property register and is currently only displaying data in 2D. It provides, in the case of 3D real estate spaces, mainly information about approximately where the 3D property unit is located. The exact extension cannot be determined solely from the property register. The owner of the 2D property unit that is hollowed out by the 3D property unit can therefore recognise that the hollowing is not located outside the boundaries specified in the property register, but it is not possible to identify the exact locations of its boundaries. To know exactly where the property boundaries are located within these 2D boundaries, the documents in the property formation dossier must be consulted; it is only there that the exact location of the property boundaries is recorded.

The property formation dossier consists of 2D drawings (usually pdf files). Currently a 3D pdf or BIM model or similar cannot form part of the property formation decision. A 3D volume therefore needs to be presented in the form of 2D drawings and verbal description.

Stockholm Municipality has implemented a project to visualise 3D property units within the area of the municipality in the form of volumes that are combined with an existing 3D city model. The project has not focused on detailed and accurate volumes, but instead on an overview design and location in relation to the borders of other properties and in relation to the location of buildings, in order to be able to make a rough assessment of the location and design of the respective 3D property units.

There is today no national system for registration or storage of 3D files such as BIM files. Today, this results in that many files are stored locally e.g. by the City of Stockholm.

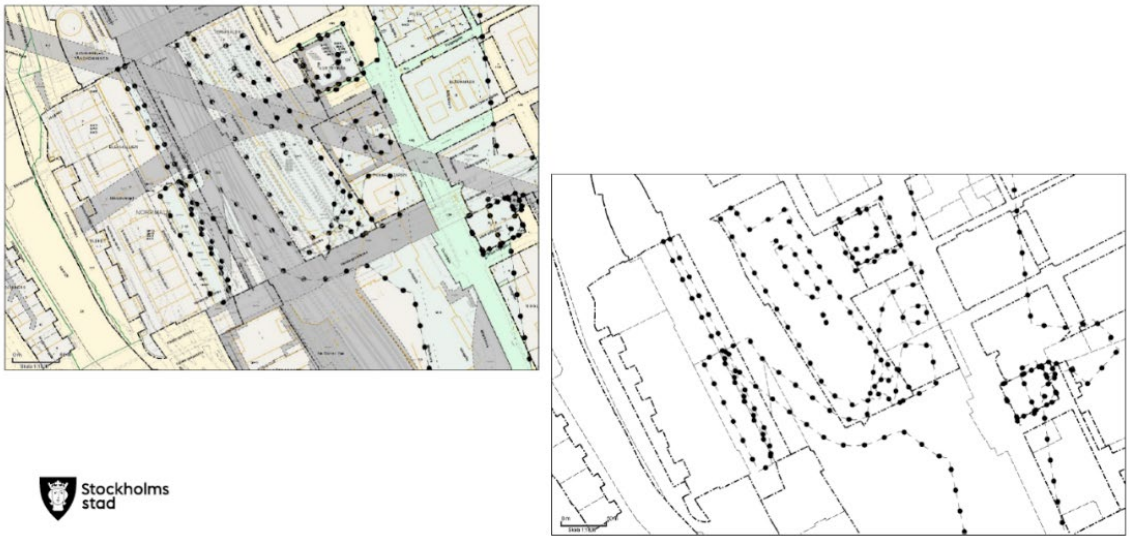


Figure 1. Selection from the cadastral index map used in the City of Stockholm. The left image includes all RRRs as well as buildings and other infrastructure, while the right image only shows real property boundaries (3D property boundaries are displayed by a filled circle on the dashed line). Adapted from Larsson, Nordqvist-Darell (2021)

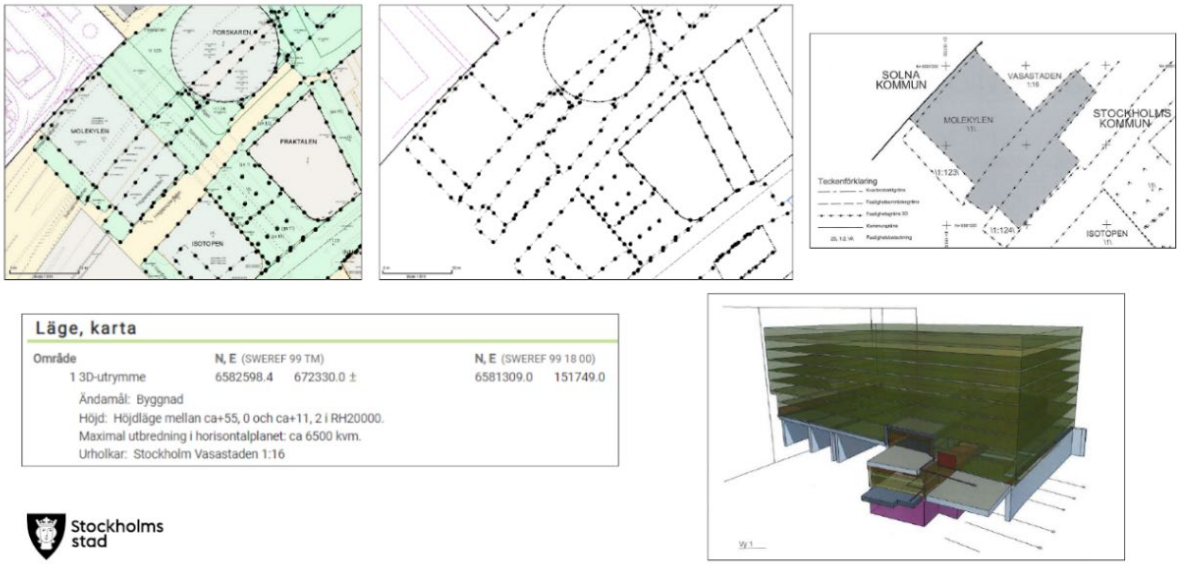


Figure 2. Top right and top middle: Selection from the cadastral index map used in the City of Stockholm. The left image includes all RRRs as well as buildings and other infrastructure, while the right image only shows real property boundaries (3D property boundaries are displayed by a filled circle on the dashed line).Top right: Map from property formation dossier including 3D property units. Lower left: Textual information about a 3D property unit in text as part of the land register, the only information is approximate maximum "footprint" by the 3D property unit, coordinates for the centre of the 3D property unit, as well as approximate maximum and minimum height position for the 3D property unit. Lower right: Screenshot from 3D model of 3D property unit, used as part of the property formation decision. Adapted from Larsson, Nordqvist-Darell (2021)

1.2 Aim and method

The paper addresses problems and challenges concerning visualisation of 3D property boundaries in Sweden based on experiences from a 3D property project in Stockholm. Focus lies on legal issues, although other aspects are mentioned as well.

The methods used in this research are the study of the cadastral and other project documents kindly provided by Stockholm municipality, supplemented with interviews of participants (e.g. cadastral surveyors, 3D visualisation experts and geodata strategists) from the municipality participating in the property formation project.

2. SWEDISH 3D PROPERTY RIGHTS

3D property units are real property limited by vertical as well as horizontal boundaries. Examples are ownership apartments and other building constructions such as tunnels, parking garages and other technical installations. It has been possible to form 3D real property units in Sweden for almost two decades. The Swedish national registration system, the national real property register, includes a textual description as well as a traditional, two-dimensional map, normally consisting of a scan of the legal map document produced during the property formation process. A traditional, two-dimensionally delimited, property is an area of land and/or water with attached property fixtures. The two-dimensional property has no upward or downward limitation, making it include in theory all air upwards into the sky and the ground down to the centre of the earth. In practice, the extension above and below ground is limited by how much the property owner can use. When the law came into force in 2004, it became possible to form properties also with horizontal boundaries, forming three-dimensional (3D) property units. For further information on the Swedish real property system, see Larsson et al. (2018).

The extension of a 3D property is thus bounded both horizontally and vertically. Compared with other jurisdictions (see e.g. Paulsson, 2007), Sweden has no specific legal rules for how to draw or visualise the cadastral boundaries in relation to the physical building construction. Since the 3D property shall contain a building or facility (Swedish Real Property Formation Act), the boundaries shall in principle follow the construction. However, according to the recommendations, there is a possibility to also include a small volume of air in the property unit in order to include protruding construction details for e.g. maintenance if deemed appropriate.
The Swedish national registration system, the national real property register, includes a textual description as well as a two-dimensional map, normally consisting of a scan of the legal map document produced during the property formation process. The property formation decisions presented in the cadastral map contain a mixture of properties and rights which are in some cases delimited in height and in some cases have no definite limitation in height. The decisions may also contain rights that are not specifically located within the properties at the time of the decision.

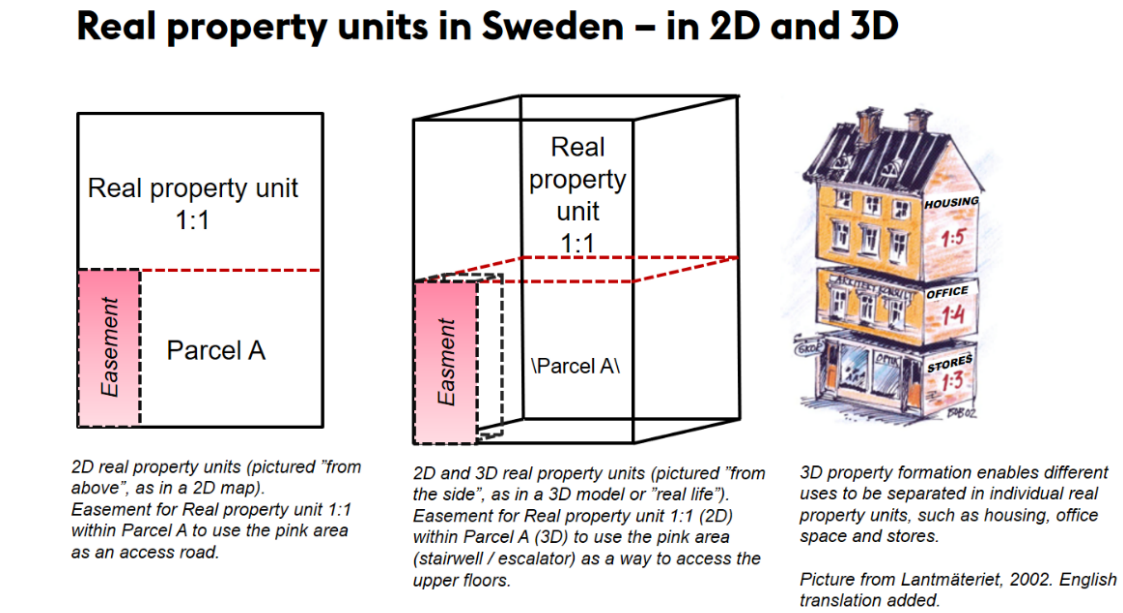


Figure 3. Description of difference between 2D property formation and 3D property formation in Sweden. Adapted from Larsson, Engström Askelin (2015)

3D property units have been possible to create in Sweden for about 15 years and the numbers are constantly growing. The complexity of design increases and several different 3D property units are located within the same 2D area in several locations.



Figure 4. Selection from cadastral index map used in the City of Stockholm, showing around 50 of the close to one thousand 3D property units registered within the Stockholm municipality. City of Stockholm 2023

There has in recent years been published several publications concerning 3D property formation in Sweden focusing primarily on the legal aspects as well as visualisation of three-dimensional RRRs. See e.g. Andrée et al. (2020); Larsson et al. (2018, 2020, 2023), Seipel et al. (2020).

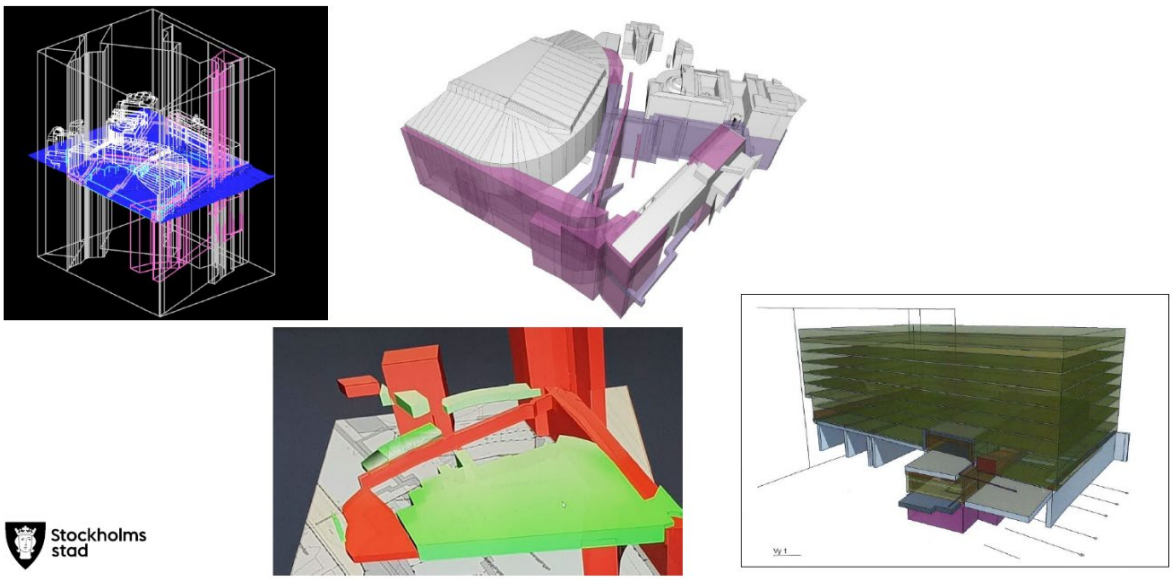


Figure 5. Test with visualisation of 3D real property boundaries and volumes. See e.g. Andrée, et al. (2020), Larsson et al. (2020), Seipel et al. (2020), Larsson et al. (2018, 2023)

Nationally and internationally there has been conducted previous research in this field, but we have not found research focussing on the exact same conditions. Examples where 3D models have been in focus are SmartBuilt (2018; 2021), Sun et al. (2019); Sun et al. (2021), Sun (2022). Analogue real property information that has been digitised into 3D models have been addressed in for example SmartBuilt (2020). Swedish 3D property boundaries have been researched in e.g. Larsson et al. (2020), Seipel et al. (2020), and Sun et al. (2019).

3. CASE STUDY

The case study worked on creating a local 3D model for the city of Stockholm where the information is saved in an internal system. The project was based on the use of existing tools and data. Height information (highest and lowest height) for existing 3D property units has been extracted from the textual part of the real property register, the maximum extent (area) has been retrieved from the cadastral index map. The data has then been processed with Feature Manipulation Engine (FME) to create volumes that correspond to the maximum extent of the respective 3D property units (i.e. the volume within which the entire 3D property unit fits). The volumes are saved in a separate internal database that can be read together with other existing databases, such as a 3D city model (including ground model and building model).

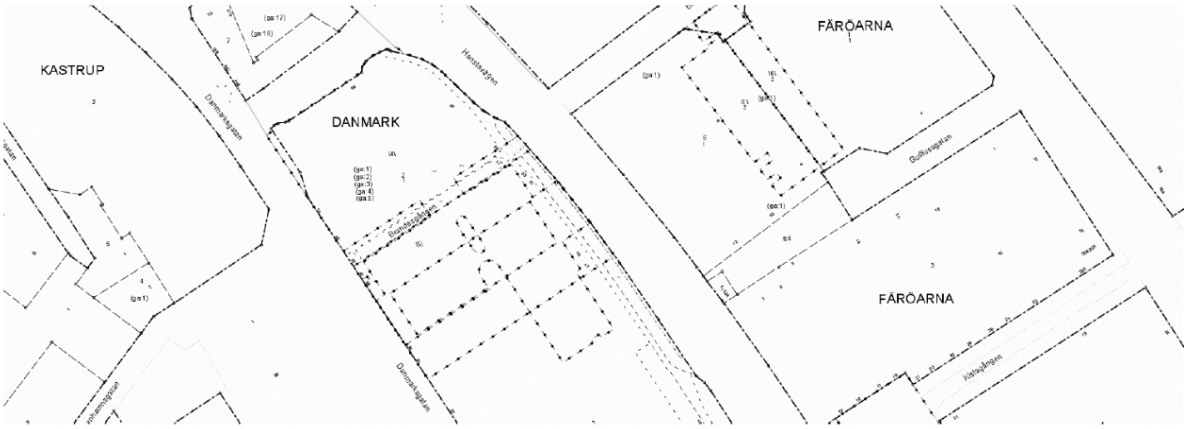


Figure 6. Representation of 2D and 3D property units in the existing cadastral index map. 2D property lines are illustrated with a dashed line, maximum spread of 3D property units are illustrated with a dashed line with filled circles on each section. Adapted from Larsson, Nordqvist-Darell (2021)

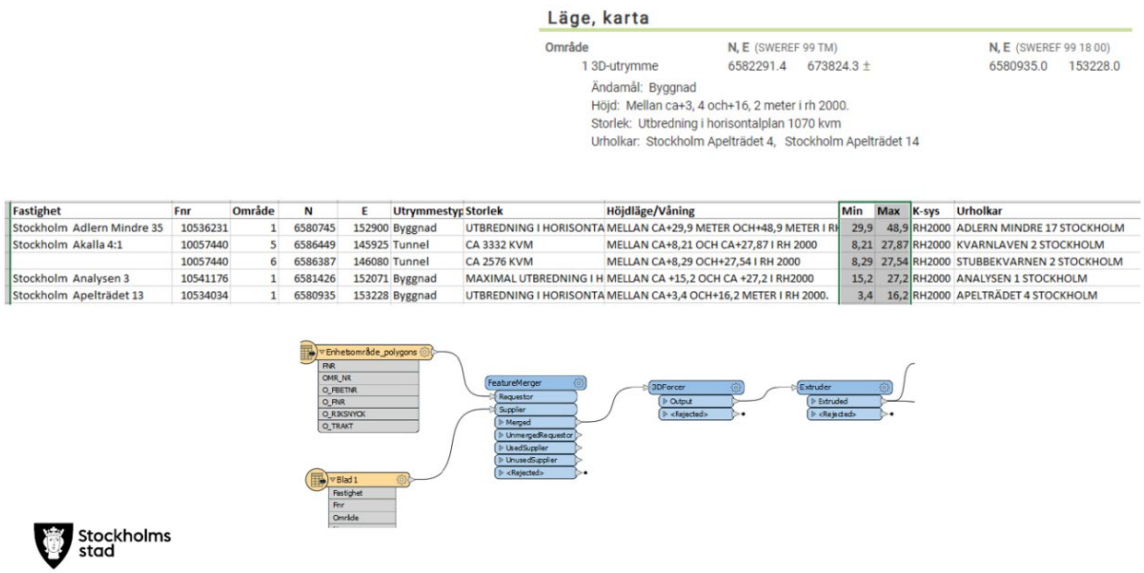


Figure 7. Existing 2D data being used for the project to create 3D volumes. Height information retrieved from the real property registry (top right) and surface spread from the Cadastral Index Map, the data is then processed using FME. Adapted from Larsson, Nordqvist-Darell (2021)

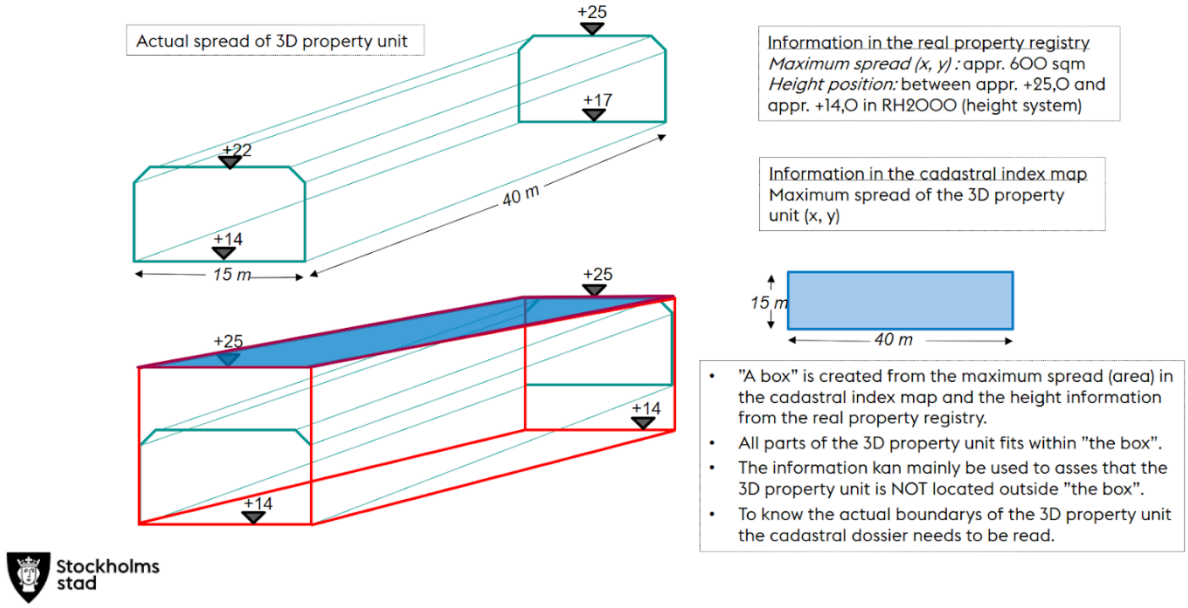


Figure 8. Illustration of specification of 3D real property units in the Swedish real property registry and cadastral index map. The red square illustrates the general 3D volume created in the case study. Adapted and translated from Larsson, Nordqvist-Darell (2021)

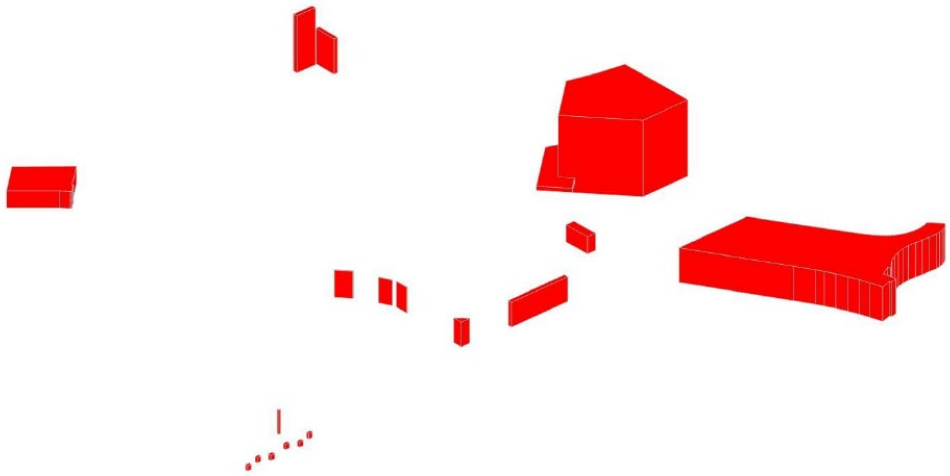


Figure 9. Picture from the database containing 3D property units. Adapted from Larsson, Nordqvist-Darell (2021)

Manual processing of the volumes was done when needed, including for very extended 3D property units (e.g. railway tunnels), where the highest and lowest heights resulted in the 3D volume for the tunnel ended up above ground in some parts, as well as where a smaller part of the 3D property unit (e.g. stairwells on a lower level than the rest of the property unit) means that the total spread is perceived to be greater than it actually is if not adjusted. In these cases, the 3D volume has been reduced to more accurately account for the actual spread, however none of the 3D volumes have a complete accuracy.

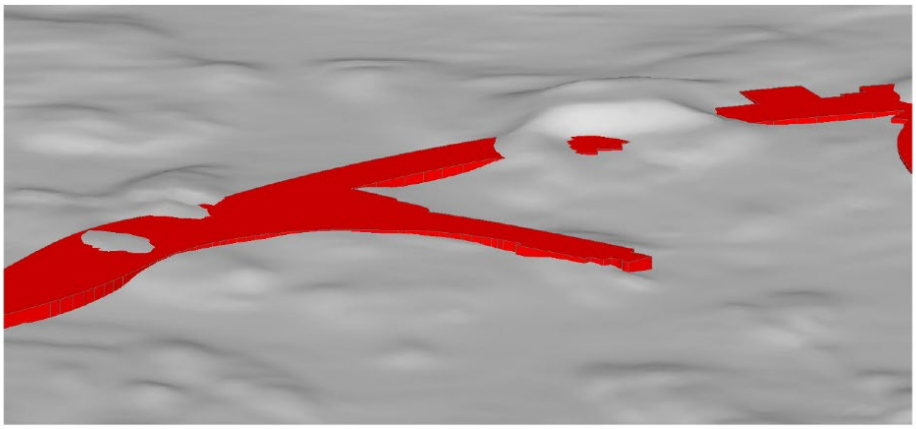


Figure 10. Illustration of specification widespread 3D property unit (tunnel) that appeared to be located above ground before manual adjustments. Red volumes represent the created 3D volume, grey spread is a representation of the ground model. Adapted from Larsson, Nordqvist-Darell (2021)

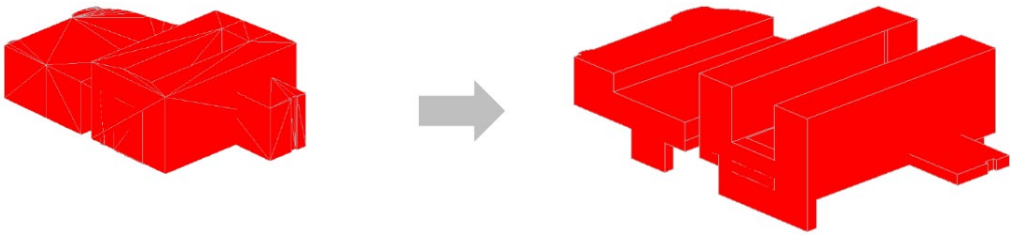


Figure 11. Illustration of 3D volume before and after manual adjustment. Adapted from Larsson, Nordqvist-Darell (2021)

Once the volumes had been produced, they were visualised together with the 3D city model (and/or ground model). Manual processing produced images with the highest possible readability. Images from suitable angles have been saved as pdf files that become available to case managers.

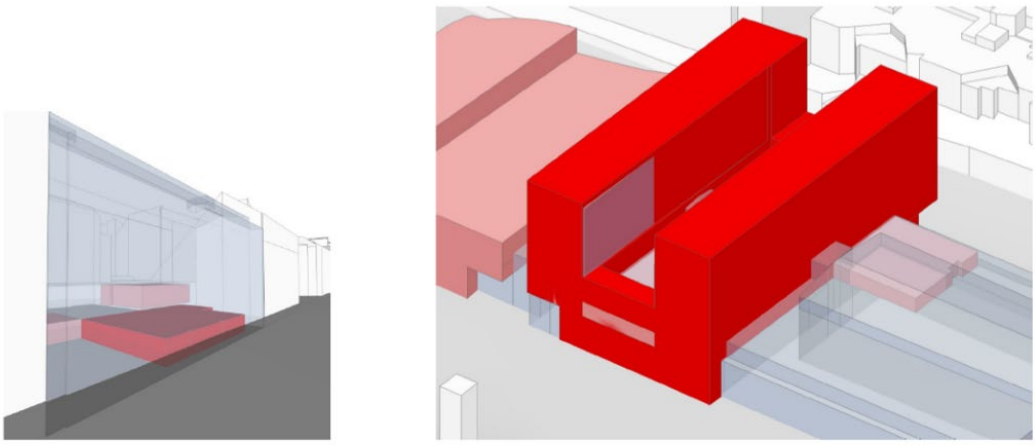


Figure 12. Illustration of 3D volumes (red) presented and visualised in combination with the 3D city model. Adapted from Larsson, Nordqvist-Darell (2021)

The project of visualising existing 3D property units started with the goal of providing a clearer picture of the design of 3D property units within the municipality of Stockholm and thus being able to streamline and save time in issuing building permits, town planning, administration, permit review and other legal tasks in municipal operations. A better and more accurate representation of property boundaries leads to greater legal certainty and minimises incorrect decisions and is a prerequisite for a fully digitised civil engineering process. The aim of the project was to be able to present 3D property units in the form of 3D volumes to make them easier to understand, especially for users who lack specialist competence in the field but need the information for their handling. The 3D volumes are intended to be used as a supplement to the property register and the documents in the executive acts.

The target group for the project results was administrators at the city planning office in the city of Stockholm who come into contact with 3D property units in their cases, mainly building permit administrators, administrative surveyors and plan administrators, with an initial focus on building permit administrators.

The officers can access the information by clicking on the affected 3D property unit area in the existing map system, then a picture will appear where you can see the relevant documents from the property formation dossier where the 3D property unit area was formed, and the selected images of the 3D visualisation. The files in the system are attached with a shorter text about where the 3D property unit is located and what it consists of, for example "garage in two floors underground". This text alone may be, for example, sufficient for a building permit officer to be able to ascertain that a building permit does NOT affect the 3D real estate space in the event that the application concerns changes within the building above ground. The 3D volumes can also give indications of whether the requested action is located within or outside the current 3D real estate space.

A minor evaluation by building permit officers has been made as part of the project and the results indicate that the individuals who have tested the new features to visualise 3D property units believe that the information can help in the daily work of building permits when these are located within or close to 3D property units. The project is intended to be continued by investigating more accurate 3D volumes to be created alongside new property formation decisions, i.e. with the use of BIM models or other 3D models displaying 3D property units and RRRs.

4. ANALYSIS AND DISCUSSION

The Swedish example is a description of a problem often encountered in the real property formation process of 3D properties. This approach to the problem shown in the paper has not to the authors' knowledge been noted in earlier research and is thus of interest for the scientific community in Sweden and abroad.

The results of this project is in line with the previously mentioned research on 3D real property, showing that there is a need for better registration of 3D RRR. It is in the current situation not possible to see volumes in relation to the real-world scenario. The experience of

the project is that it is beneficial for the cadastral procedure that volumes are visualised with more detail than their maximal extension. A development concerning improving the current registration of 3D volumes could focus of different challenges, such as what data quality is needed on object level as well as thematic level, the use of different colours, symbols and textures for visualisation for specific stakeholders and groups of users, which data is legally binding and what data is informative, just to mention some examples. The registration of 3D cadastral information can be seen as a paradigm shift, going from a 2D focus to a 3D focus in the cadastral index map. This shift, however, needs to include research regarding legal issues, such as what information is legally binding and how data is to be displayed in a correct and informative way.

Currently, a research project planned for 2023-2025 within the Swedish Smart Built Environment programme (SmartBuilt, 2023) will analyse possibilities and challenges concerning extended registration and visualisation of 3D real property in the national real property register. The project is a cooperation between academia, Lantmäteriet (the Swedish mapping, cadastral and land registration authority), municipalities as well as private companies. The Smart Built Environment programme is a strategic innovation programme for outlining how the built environment sector can make use of new opportunities of digitalisation.

5. CONCLUSIONS

The purpose of the visualisation was to make 3D real property information more accessible to users of cadastral information, especially if they lack specialist knowledge but need to use 3D information as part of their employment at Stockholm Municipality, such as cadastral surveyors and planners. The 3D volumes could be used as a supplement to the information stored in the national real property register and the cadastral dossiers.

The results can be used as a component for the development of a national three-dimensional cadastral index map as well as for enabling 3D models as part of the formal cadastral property formation procedure.

The procedure used in the project, where simple representations of the 3D property units were created, could with quite small effort possibly be used to visualise all 3D property units in the Swedish real property register by using FME. However, there is today no national system for registration or storage of 3D files such as BIM files. This results in that many files are stored locally, e.g., by the City of Stockholm. To create a national system for registration and storage of 3D files would be beneficial on a national level, especially if a national approach of creating 3D volumes would be attempted.

The project has also shown that it would be beneficial to investigate further the possibilities of creating more accurate and detailed 3D volumes.

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BIOGRAPHICAL NOTES

Karolina Larsson is a cadastral surveyor working at the Cadastral Authority of the City of Stockholm (Lantmäterimyndigheten i Stockholms kommun), concentrating on 3D real property units and property formation. She holds a MSc degree in Land Surveying, concentration on Spatial Planning, from the KTH Royal Institute of Technology. She has been, and is currently, participating in several projects looking at possibilities to transform to a 3D cadastre as well as use of 3D models in cadastral procedures in the Swedish context

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Modeling data dissemination processes as part of the future LADM development

Josip KRIŽANOVIĆ, Miodrag ROIĆ and Doris PIVAC, Croatia

Key words: land administration, dissemination, data, processes, modeling, LADM, OGC

SUMMARY

Land administration (LA) is dynamic, and it cannot be understood, built or improved unless the processes associated with it are understood. One of the core standards in the domain of LA, namely ISO 19152 Land Administration Domain Model (LADM) provides conceptual data models for land administration systems (LASs). However, it does not cover all LA functions in its current edition and is currently under revision to include more LA-related parts such as land registration, marine georegulation, land valuation, spatial planning and implementation. Implementation aspects are expected to include technical models and processes with active participation of Open Geospatial Consortium (OGC). Notably, no official progress was yet made regarding the Part 6: Implementation, therefore this paper aims to present viability of the proposed methodology for modeling LA data dissemination processes on one of the most common use cases in Croatian LAS. The utilized methodology includes steps such as identifying use case, formalization of current state of the process, process breakdown and lastly optimization and formalization of improved state of the process. During the process breakdown step of the said methodology, process elements were grouped into three groups namely, actors, activities and resources. Furthermore, it was determined that actors and resources can be modeled with existing LADM classes, whereas activities could not. Moreover, two solutions for extending LADM with process-related classes were identified in journal articles, but since OGC participation is announced for the development of Part 6, it was expected to examine OGC process related standard, namely API-Processes-Part 1: Core. Classes which relate to process activities were compared in terms of attribute analysis. Differences and similarities were determined, and it was discussed that process-related extension should include class for activities, whereas attributes might vary depending on the system requirements and process tasks.

Modeling data dissemination processes as part of the future LADM development

Josip KRIŽANOVIĆ, Miodrag ROIĆ and Doris PIVAC, Croatia

1. INTRODUCTION

One of the popular definitions describes land administration (LA) as the process of determining, recording, disseminating and updating information about the relationship between people and land (ISO, 2012). In addition to defining relations of people to land, LA informs us on the 'how', the 'what', the 'who', the 'when' and the 'where' of land tenure, land use, land value, and land development (UN-GGIM, 2020). Simply put, LA is dynamic, and it cannot be understood, built, or improved unless the processes associated with it are understood; moreover, if the processes are well organized and integrated, the structure of institutions that manage them is less important (Williamson et al., 2010).

Given the said description of LA, two general process groups in which users interact with LA can be identified, namely registration and dissemination. Registration adds new information to the register, while dissemination returns the requested information to the user. Despite both these processes being important parts of LA dynamism, data dissemination processes were in most studies deemed as simple processes. However, it was identified that their complexity rises in use cases which involve multiple authorities operating different services and procedures (Križanović and Roić, 2023a). Land data is the core of any land administration system (LAS). Moreover, data cuts across all Sustainable Development Goals (SDGs) in terms of evaluating and monitoring of indicators, but also supporting day-to-day activities of people and the interaction with built and natural environment. The linking of the data and the people increases with the growing use of ICT and web technologies (UN-GGIM, 2020). The emphasis of the importance of data is also supported by the United Nations Integrated Geospatial Information Framework (UN-IGIF), which identifies data as standalone strategic pathway and calls for the development and identification of best practice registration, maintenance and dissemination of integrated geospatial information. Notably, the need for cross-sector and multidisciplinary collaboration is emphasized as well (UN-IGIF, 2023). One of the ways to enhance links between data and the users may be with the improvement of existing data dissemination processes, however prior to improving existing practices it might be useful to utilize techniques such as process modeling. Process models are recognized to provide better understanding of the processes, enable communication between the involved stakeholders, optimize current procedures and/or process elements, and lastly to predict impact of changes to dissemination strategies such as introduction of new technologies or policy reforms (Križanović, 2023).

One of the core standards in the domain of LA, namely ISO 19152 Land Administration Domain Model (LADM), provides semantics of the domain as well as shared ontology, and defines the terminology. Furthermore, it is capable of supporting the progressive improvement of LA and could potentially be used to support organizational integration, for example, between often disparate land registries and cadastral agencies (Mađer et al., 2015). However,

the current edition of LADM is more oriented towards modeling static components of LA, whereas dynamic components are planned in the second edition of the standard. The LADM II is projected to be published as multipart, covering land registration in Part 2, marine georegulation in Part 3, land valuation in Part 4, spatial planning in Part 5 and lastly implementation in Part 6. The Part 6, which is of interest to this paper, is expected to include technical models and processes with active participation of the Open Geospatial Consortium (OGC). Notably, no official progress was yet made regarding the Part 6 of the LADM Edition II (Lemmen et al., 2023).

The aim of this paper is to present research results related to modeling of LA data dissemination processes in context of LADM developments and to investigate possible utilizations of the OGC standard related to processes, namely OGC API-Processes-Part 1: Core Standard. Notably, this standard is projected to be extended as multipart as well, including Part 2: Deploy, Replace and Update and Part 3: Workflows and Chaining. Furthermore, the authors will examine one of the most common data dissemination use cases in Croatian LAS, which depicts the procedure for obtaining cadastral and spatial planning data for a certain property of interest. This use case was colloquially named "Dissemination of Land Use Constraints" in Križanović and Roić (2023a) and provides answers to interested party how the property of interest should be developed in accordance with spatial planning regulations. The identified use case is modeled and analyzed by following the methodology proposed by Križanović and Roić (2023b) which is described in the next section.

Regarding the structure, the research methodology is outlined in the next section as well, consisting of the resources and tools used to examine the said use case. Subsequently, the analysis and results section depicts the formalization, analysis and improvement recommendations of the examined use case. The paper ends with discussion and conclusion accompanied by future work recommendations.

2. METHODOLOGY

The research began by inspecting relevant bibliographic databases such as Web of Science and Scopus. Additionally, the literature search included domain-relevant conferences such as those organized by the FIG, e.g., LADM workshops and FIG Working Weeks. Conference papers/proceedings are deemed to be an essential part of the research area's published literature according to Glänzel et al. (2006) and Lisée et al. (2008), whereas the scientific value of the FIG conferences and LADM workshops to the overall LADM development was recognized by Polat et al. (2022). Search strings included combinations of keywords such as 'land administration system', 'processes', 'data dissemination', 'modeling' and 'LADM'. Since the modeling of LA processes is expected to be included in the second edition of the LADM, an overview of papers that are thematically relevant to the second edition was presented by van Oosterom et al. (2022), including 20 articles on LADM developments and innovations. Furthermore, a very helpful bibliometric analysis was conducted by Polat et al. (2022), in which papers related to the LADM published in the period of 2012 to 2020 were analyzed. In the current year, the 2023, at the FIG Working Week in Orlando USA, an overview of developments of Edition II of the LADM was presented by Lemmen et al.

(2023), including the development timelines and expected publication dates for new parts of the LADM. Notably, the cooperation with OGC for the development of Part 6: Implementation was announced, meaning that the OGC process-related standards should be considered when conducting research in the field of standardizing processes as part of the future LADM developments. Regarding the topic of this paper, namely LA processes and in particular data dissemination processes, research papers such as Križanović and Roić (2023a, 2023b) contributed with a proposed methodology and model for describing LA data dissemination processes. Another view of extending LADM with processes was presented by Vranić et al. (2021). Despite differences in developed models between the said papers, both could be utilized as starting points for the future development of Part 6 of the LADM II.
The process modeling methodology (Figure 1) developed by Križanović and Roić (2023b) was utilized in this paper on a real-world use case from Croatian LAS.

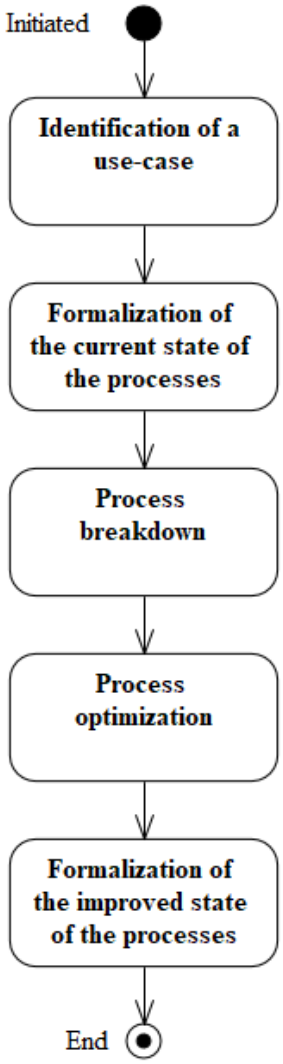


Figure 1. Methodology used for modeling LA data dissemination processes. Source:(Križanović and Roić, 2023b)

The first step of the proposed methodology is identification of a use case, which in this paper is already identified by previous research, namely the dissemination of land use constraints. This use case is one of the most common use cases from Croatian LAS in which cadastral certificates are required to collect data from other registers, in this case the spatial planning. The second step, formalization of the current state of the process, will be carried out using activity diagrams of the Unified Modeling Language (UML). The current state of the examined use case will differ from the model developed by Križanović and Roić (2023a) in terms of focusing more on executable activities conducted by the involved stakeholders rather than the general workflow of the process as described in the said paper. Following the formalization of a process comes the next step, namely process breakdown, in which the identified process elements were analyzed and matched with existing LADM classes Furthermore, optimization of certain activities was explored in terms of achieving automation and interoperability and formalized by a conceptual model of the integrated LAS service, i.e., the improved state of the process. Improved state of the process was formalized by means of activity diagram as well.

There are many techniques available for specifying processes in a formal and abstract way, but since UML was utilized in the first edition of the LADM, it is expected to use the same modeling language for future editions of the standard. Moreover, UML is widely adopted as a modeling tool within the domain of LA and was employed in other domain-relevant sources outside of the LADM, e.g., Pržulj et al. (2022) and Zevenbergen et al. (2007). Furthermore, in case modelers do not possess high level of competence in process modeling, it might be useful to check process modeling guidelines when formalizing current and improved state of the process use cases, e.g., the Seven Process Modeling Guidelines (7PMG) which were developed by Mendling et al. (2010).

3. ANALYSIS AND RESULTS

Core LA data is usually distributed between different institutions each with legally determined rights and functions. Moreover, each of the responsible institutions have their own view and interpretation of their importance, use, application and usually employ different procedures (Beck et al., 2023; Kalogianni et al., 2020). The said cases are present in Croatian LAS as well. The examined use case represents a process in which users are required to collect data from more than one register, to achieve certain goal, namely getting the information how the certain property should be developed in accordance with spatial regulations.

3.1 Formalization of the current state of the process

In order to complete the examined process (Figure 2), it is necessary to collect cadastral information, in this case, the certificate named the Cadastral Map Copy. This certificate must be submitted along any request within the spatial planning service, in this case the Request for Location Information. Furthermore, the process is split between two services, namely the Joint Information Service (JIS) and e-Permit. JIS is the service for cadastral data and e-Permit is the service for spatial planning data. More about the services can be found in (Križanović and Roić, 2023a).

The stakeholders involved in the process include LAS User, the Cadastral Service (JIS) and Spatial Planning Officer and are represented with vertical partitions. The activities of each of the involved stakeholders are represented with round-edged rectangles within each respective partition. Objects, or in this case requests and disseminated certificates are represented by rectangles (Figure 2).

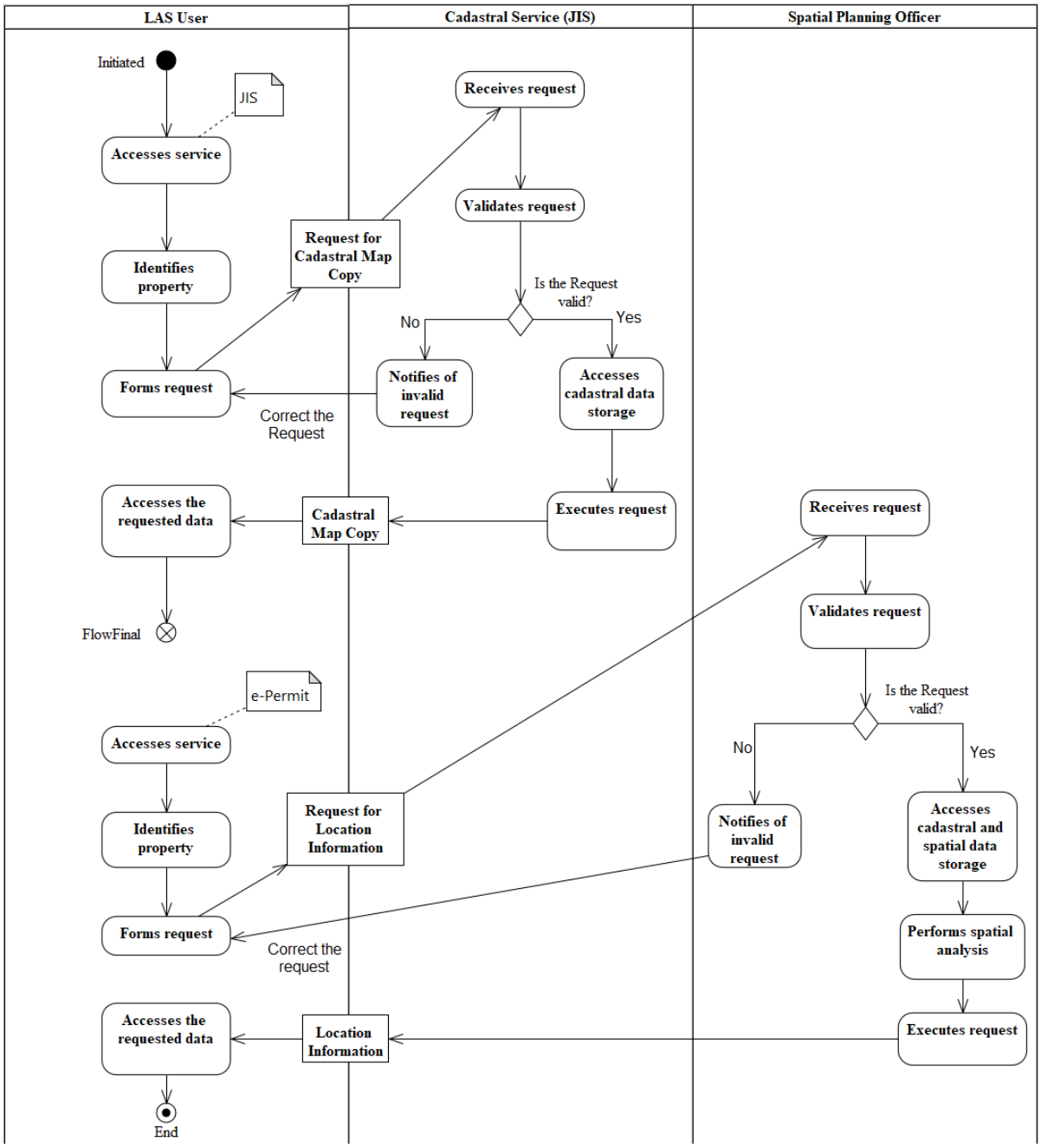


Figure 2. Current state of the examined use case. Source: Own compilation

The use case begins with accessing cadastral service (JIS) and identifying property of interest. In this case, the property identification can be conducted in multiple ways such as searching by property identification (cadastral municipality and parcel ID), searching by address of the

property or manually by browsing the cadastral map. Once the property of interest is identified, a request for cadastral certificates can be submitted (in this case the Cadastral Map Copy). Once the request is submitted it is received by the service and validated automatically. In case of invalid request, e.g., user is not logged in with an authorized account, service notifies the user to correct the request. In case of valid request, service accesses the cadastral data storage and prepares it in the requested format which in this case is PDF, i.e., executes the request. Upon receiving the requested certificate, user can access the certificate to either view or download it. The process continues on the spatial planning service (e-Permit) in which user can select one of the available requests (in this case the request for Location Information). The Cadastral Map Copy is used to identify property of interest and users are obliged to submit it when forming the request. Upon fulfilling the request for Location Information, it is submitted and received by one of the officers in the Spatial Planning Office which is responsible for the area in which the property of interest is located. Furthermore, the request is validated manually by the Spatial Planning Officer who in case of invalid request, e.g., the user has selected wrong responsible spatial planning office, notifies the user of reasons why the request is invalid. On the other hand, in case of valid request, the Spatial Planning Officer is required to access both cadastral and spatial planning data to determine which spatial planning zone and regulations affect the property of interest. This activity is named spatial analysis and it can be performed by overlapping the different sets of data and manually determining the spatial zone or by performing spatial analysis actions such as intersection and retrieval of attributes. Once the spatial analysis is completed and Location Information prepared, the Spatial Planning Officer disseminates the requested certificate via spatial planning service to the user, who can view or download the requested certificate. Notably, the timeframe for validation and execution of a request for Location Information is regulated by law and should be fulfilled in a span of eight days.

3.2 Process breakdown

There are many definitions of the processes, but what emerges from those variations is as follows: the activities associated with business process are performed by actors playing certain roles, consuming resources, and producing other resources (Mili et al., 2010). Notably, this definition originates from the domain of process modeling. By following the said definition, use case formalized in the previous sub-section is broken down into three groups of elements, namely actors, resources and activities, as shown in Table 1. Additionally, process elements are matched with existing LADM classes which can be used to denote identified process elements.

The results of process breakdown include identification of three actors which can be denoted as instances of classes LA_Party, LA_PartyGroup and LA_PartyMember. Notably, Cadastral service (JIS) appears as both actor and resource, as it can be observed from different perspectives, the first being a software system responsible for conducting process activities, whereas in second perspective it can be observed as a resource of Cadastral Authority. The same applies for Spatial Planning service even though it does not appear in this use case as an actor. Furthermore, the results include identification of ten unique activities which may occur several times under different circumstances, e.g., validation of request occurs both within the cadastral service and by the spatial planning officer. Activities are out of scope in the current edition of LADM, but were included in both proposals of extending LADM with processes by

Križanović and Roić (2023b) and Vranić et al. (2021). Lastly, the examined use case utilizes eight resources which can be denoted as instances of classes LA_Source, LA_AdministrativeSource or LA_SpatialSource. Notably, some of the resources such as requests are made by the user whereas some of the resources are derived from other resources, e.g., Cadastral Map Copy is generated from cadastral data.

Table 1. Results of process breakdown

Process element	**Identified element**	**LADM Match**
Actor	LAS User	LA_Party, LA_GroupParty, LA_PartyMember
	Cadastral Service (JIS)	
	Spatial Planning Officer	
Activity	Accessing service	/
	Identifying property	
	Forming request	
	Receiving request	
	Validating request	
	Notifying	
	Accessing data storage	
	Executing request	
	Accessing requested data	
	Performing spatial analysis	
Resource	Cadastral service	LA_Source, LA_AdministrativeSource, LA_SpatialSource
	Request (Cadastral Map Copy)	
	Cadastral data storage	
	Cadastral Map Copy	
	Spatial Planning service	
	Request (Location Information)	
	Spatial planning data storage	
	Location Information	

Breaking down the complex units such as processes into smaller, more manageable components, enables identification of elements which can be optimized. For example, the examined use case utilizes two different services, includes several activities which are almost the same, such as identification of property, request formation, multiple accesses to data storages and some of them are prone for errors by the actors. Moreover, one of the major flaws of the current state of the examined use case is the fact that from user's perspective entirety of a process is conducted in electronic environment but is not fully automated from execution perspective. The part of the process which occurs within the spatial planning service is subject to mistakes in request formation, as the validation of request is not conducted by the service but by the spatial planning officer. Additionally, the execution of a

request heavily depends on staff capabilities of the spatial planning office in charge of the area in which the property of interest is located. In terms of the LADM developments, process breakdown step might be of a great importance, because it can be utilized to determine which process elements can be modeled with existing LADM classes and which ones should be included in future LADM extensions such as activities.

3.3 Process optimization and formalization of the improved state of the process

With the advancement of Web technologies, the service-oriented approach has become increasingly popular to disseminate data from different providers, whereas interoperability is critical to the access and integration of Web services (Zhang et al., 2020). The examined use case could be improved by developing a single service in which LA authorities could share their services, i.e., visualization and access to stored data. Moreover, it might be possible to implement fully automated procedures to support various use cases of data dissemination processes. The conceptual solution for the improved state of the examined use case is depicted in Figure 3 below.

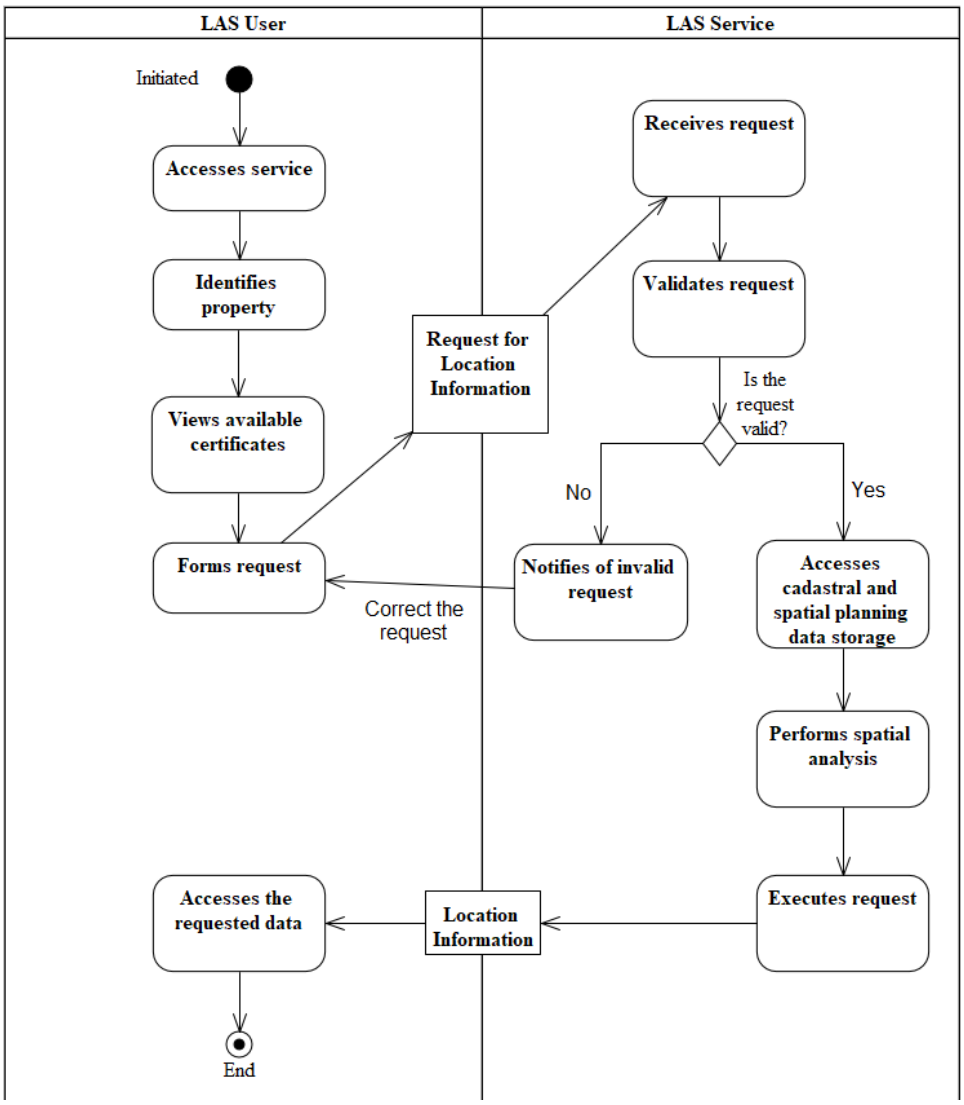


Figure 3. Improved state of the examined use case. Source: Own compilation.

In the improved state of the examined use case, LAS User accesses single service colloquially named LAS Service. Upon accessing service, it is required to identify property of interest and view available certificates. In this case the request for Location Information is selected and submitted. LAS Service, which is supposed to be software solution, receives request and validates it. In case of an invalid request, the user is notified and granted to correct the request. On the other hand, if request deems valid, service accesses cadastral and spatial planning data and performs spatial analysis to determine spatial planning zone and regulations affecting the property of interest. Following successful spatial analysis, request is executed, and the required certificate is disseminated to user for either viewing or downloading. Notably, in case LADM II would offer examples of best practices for data dissemination processes, the improved state could be referred to as standardized state.

4. DISCUSSION

Despite no official progress regarding the Part 6 of the LADM development yet, it was recognized that the process models should be developed at conceptual level to enable comparison and further understanding of different land administration systems (LASs) processes. Additionally, from such models it could be possible to identify most suitable practices and develop standardized workflows (Lemmen et al., 2018). The process modeling methodology which was utilized in this paper could be used as a starting point in developing standardized process models. Describing real-world use cases from different LASs could enable comparison of similar use cases and identification of most suitable practices. Apart from comparing use cases in different LASs in search for standardized process models, it might be useful to utilize ”Best Practices for Spatial Data on Web” (W3C and OGC, 2023) and ”Data on the Web Best Practices” (W3C, 2017). So far seventeen best practices for spatial data on Web are documented by World Wide Web Consortium (W3C) and OGC. Some of them might be highly relevant to the examined use case in this paper, such as ”make your spatial data indexable by search engines”, ”link resources together to create the Web of data” and ”expose spatial data through convenience APIs”. Notably, other recommendations might prove useful for data providers as well. Furthermore, some of the recommendations from W3C (2017) could also apply to the examined use case and include ”provide real-time access”, ”provide data up to date” and ”provide data in multiple formats”. Following these guidelines during the optimization step of the proposed methodology, existing data dissemination practices could be enhanced significantly.

Development of Part 6 of the LADM II should include extension of the existing model with process related classes. To the knowledge of authors two solutions were proposed, the first by Vranić et al. (2021) and the second by Križanović and Roić (2023b). Vranić et al. propose extension with two new classes, namely LA_Process and LA_ProcessActivity, whereas Križanović and Roić propose extension with three new classes LA_Process, LA_Activity and LA_Event. The first proposed extension employs class LA_Process to establish relations with classes LA_Source and LA_VersionedObject, whereas the second proposal suggests class LA_Activity as a linking class with two of the existing classes, LA_Source and LA_Party. Additionally, the OGC API-Processes-Part 1: Core standard also deals with LA processes

and has developed models to describe them (OGC, 2021). In this standard, process is defined as a function that for each input returns corresponding output. Reading the said definition, it might be possible to denote OGC processes as activities from the two previously mentioned models. Additionally, by observing activities in the examined use case, each of them has a certain input resulting with corresponding output, e.g., searching by cadastral municipality and parcel ID (inputs) results with identification of property of interest (output). Table 2 below shows the attributes of activity-related classes identified in the three process-related models.

Table 2. Comparison of the activity-related classes

Author	Class	Attributes	Total
Vranić et. Al. (2021)	LA_ProcessActivity	prtID	5
		Name	
		Group	
		Description	
		Correctness criteria	
Križanović and Roić (2023)	LA_Activity	Activity ID	13
		Name	
		Description	
		Responsible party	
		Inputs	
		Outputs	
		Events	
		Start date	
		End date	
		Status	
		Constraints	
		Predecessor activity	
		Successor activity	
OGC (2021)	Resources: Process	Description	8
		ID	
		Inputs	
		Mode	
		Outputs	
		Response	
		Subscriber	
		Title	

Reading through Table 2, it is evident that the three classes share some common attributes related to description and identification, but they also have distinct attributes that are specific to their relative purpose. LA_ProcessActivity seems to focus on categorization and quality control by employing attributes such as Group and Correctness criteria, whereas LA_Activity class is designed to address operational aspects of activities, focusing on their initiation, execution, monitoring and completion. The attributes which contribute to this fact include

Responsible Party, Start Date, End Date, Status, Constraints, Inputs and Outputs. The OGC's class Process has attributes related to the overall management of a process, including Mode, Response, Subscriber and Title attributes. Regarding the similarities, all three classes have Description and ID attributes. This suggests that they can provide textual description, e.g., for documentation or explanation purposes. LA_Activity and OGC Process both have an ID attribute to uniquely identify or categorize activities. Moreover, they also share attributes such as name, inputs and outputs which suggests that they can be represented by human-readable name or label and require data inputs to produce data outputs. Notably, the most important similarity is that all three of the examined process models include activity-like classes, whereas attributes can always be changed to answer process tasks or system functionalities.

5. CONCLUSIONS AND FUTURE WORK RECCOMENDATIONS

Future LASs are expected to be fully electronic with efficient electronic services and processes. Standards for land administration policies, laws, organizations, financing, transactions and especially data and technology are increasingly available on all levels (UN-GGIM, 2020; UN-IGIF, 2023). The importance of data is recognized globally, and it is increasingly recognized that LASs, processes and services should support and be organized around user requirements.

In this paper, one of the most common use cases of data dissemination processes in Croatian LAS was analyzed, namely the dissemination of land use constraints. The authors utilized proposed methodology for modeling and describing LA data dissemination processes to prove its viability on a real-world use case. It is evident that the procedure is still reliant on analogue thinking because of redundant activities, multiple access points and certain lack of automated procedures. Moreover, it can be concluded that the lack of integrated and interoperable services underpins the current LAS in Croatia. Integrated LASs may not be obtainable in short term, and require significant institutional, technical and political changes. By following the same methodology, it might be possible to compare similar use cases in different LASs, determine most suitable practices and finally develop standardized process models.

The development of LADM II can aid in achieving integrated LASs, especially with inclusion of other LA functions such as land valuation and spatial planning. Moreover, with the growing recognition of LADM (Kalogianni et al., 2021), it is expected that the next steps should include development of process modeling which includes use cases, process models and conceptual models of services (Govedarica et al., 2021).

Furthermore, the extension of LADM with process related classes was discussed. Two of the proposed models were identified in journal articles, whereas the third solution was found in OGC standard relating to processes. The identified classes which relate to activities were compared in terms of determining similarities and differences. Moreover, it was concluded that activity attributes can vary depending on system requirements and process tasks, but activity-related class should be considered for future LADM II developments. The approach of comparing different proposals for class attributes might prove useful to determine common attributes such as ID, name, description, inputs and outputs which could be included in the

LADM extension with processes. Notably, the OGC solution had to be included in this comparison, since it was announced that OGC will partake in development of Part 6: Implementation of LADM II. This cooperation might be highly required because it is recognized that transforming conceptual model into physical model in a production system is challenging (Bar-Maor and Smyth, 2022). Beyond the need to have a good understanding of LADM (conceptual models) the system designers need to consider additional requirements which are not covered by standards. This is where the standard interoperability between LADM and other standards such as OGC API Processes-Part 1: Core and its future extensions should be considered when developing Part 6 of the LADM extension.

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BIOGRAPHICAL NOTES

Josip Križanović graduated from the University of Zagreb Faculty of Geodesy in 2017 with his diploma thesis Land Reallocation Based on User Preferences in Land Consolidation. Since 2018, he has been employed at the University of Zagreb Faculty of Geodesy as University Assistant on Chair of Spatial Information Management. He received a PhD from the University of Zagreb Faculty of Geodesy in 2023 with doctoral thesis Modelling Land Administration System Data Dissemination Processes. His main research interests are land administration, modeling of land administration processes and the LADM.

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Doris Pivac graduated from the University of Zagreb, Faculty of Geodesy in 2014 with her diploma thesis GIS of Rivers of Croatia. Since 2016, she has been employed as the University of Zagreb, Faculty of Geodesy as University Assistant on Chair of Spatial Information Management. She received a PhD from the University of Zagreb Faculty of Geodesy in 2022 with doctoral thesis Developing a model for improvement of the metadata availability on the cadastre establishment. Since 2023 she is employed as Senior University Assistant on Chair of Spatial Information Management at the University of Zagreb Faculty of Geodesy. Her main research interests are cadastral systems, metadata standards and modelling of archival data documents regarding cadastral systems.

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The Use of Augmented Reality Models in the Serbian Utility Network Cadastre

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Key words: Augmented Reality, AR, LADM, FME, utility network cadastre

SUMMARY

The utility network cadastre in Serbia is the main register of the utility lines and rights to them, together with the property owner's rights. The legal aspects of the utility network cadastre in Serbia is organized the same way like in real estate cadastre. For this reason, the extended LADM utility network data model for Serbia is developed in previous work of the authors. In the era of different technologies and the possibilities of storing and displaying data in 2D and 3D, it is desirable to use their full potential. In the paper, the possibilities of using augmented reality data to get a better overview of the data on the field is analyzed. The augmented reality models have been developed to display different types of manholes, which are node points of underground utility lines. The models were developed through the FME (Feature Manipulation Engine) software package and allow the display of different shapes of manholes, the addition of different textures to the interior and exterior of the manhole, as well as arbitrary content of the manhole. Other utility objects can be presented in a similar way. Such models can be included in the unified LADM based data model for utility network cadastre in Serbia by extending the code list for spatial source type and adding necessary classes. This way developed models can not only be used in the field but in office condition too.

The Use of Augmented Reality Models in the Serbian Utility Network Cadastre

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1. INTRODUCTION

The utility network cadastre in Serbia is the main register of the utility lines and rights to them, together with the property owner's rights. It contains information on water supply network, sewage and drainage network, hot water network, electricity network, telecommunications network, pipeline network, gas pipeline network, and common objects. Survey, establishment and maintenance of the utility network cadastre in Serbia are defined by the Law on state survey and cadastre from 2009 (Official Gazzete, 2009). The Law states the necessity for implementing a unified information system of both the real estate cadastre and the utility network cadastre. In the previous work of the authors, the unified data model for both real estate and utility cadastre was developed based on the LADM (Radulović, 2019). Spatial data of the utilities and utility objects are stored in the 2D CAD files and often there are some divergences with the actual state. In practice, when there is change done on the utility lines by the right holders it is necessary to implement the change in the utility network cadastre. In many situations it is not done and the actual state does not correspond to the one in the utility network cadastre. Like in the real estate cadastre in Serbia, in the utility network cadastre graphical data are stored separately from alphanumeric data containing attribute data for the utilities and the rights to them. This means that the existing geodetic-cadastral system consists of several legacy subsystems that are poorly connected. Procedures in the utility cadastre are executed based on outdated data from the real estate cadastre, usually copied at some point in the past. Also when new lines are placed or some change is done, the procedure to update data in cadastre takes long time. In the meantime, it may happen that a new line needs to be placed. By inspecting the data, the last change is not visible. If the data are not correct, maintanance on the field may cause the damage on the utilities and utility objects.

In the era of different technologies and the possibilities of storing and displaying data in 2D and 3D, it is desirable to use their full potential. In the previous work, the possibility of binding the data in the utility network cadastre with 3D formats created during different projects was pointed out. To go one step further, it is possible to use augmented reality models in visualization to get the information about the utilities and utility object that can significantly improve the repair of damage to underground lines, but also significantly speed up the process of their detection (eg. when they are overgrown with vegetation, have deposits of earth and other materials), as well as determining the depth at which the analyzed line is located.

In this paper, the augmented reality models have been developed to display different types of manholes, which are node points of underground utility lines. The models were

developed through the FME (Feature Manipulation Engine) software package and allow the display of different shapes of manholes, the addition of different textures to the interior and exterior of the manhole, as well as arbitrary content of the manhole. The main advantage of the augmented reality model is reflected in the possibility of displaying the content of the manhole in a virtual reality environment, without opening it. It is enough to open the manhole once, measure its contents in detail and create a model of the manhole in digital form. In one manhole, there can be different utility lines, located at the same/different depths, of different diameters, with and without accompanying elements, such as branches, couplings, valves etc. All the mentioned elements can be modeled through FME as well as exported to the appropriate format for display in an augmented reality environment. Other utility objects can be presented in a similar way. Such models can be included in the unified LADM based data model for utility network cadastre in Serbia by extending the code list for spatial source type.

This paper is structured as follows. Second section describes the technology and the methodology used in this paper. Third section presents the development of the FME model for visualization of manholes in one of the augmented reality applications. Fourth section presents an example of visualization of developed model. Fifth section presents how this result fits in the already developed LADM profile for utility network cadastre. Conclusions and future work are given afterward.

2. METHODOLOGY

The development of modern technologies for the visualization of geospatial data contributes to a better understanding of spatial data, the perception of their mutual relationships in space and enables more detailed analysis. Today, modern technologies such as virtual reality (VR) and augmented reality (AR) are increasingly applied in the world in various fields, such as: automotive (Himperich, 2007) and aviation industry (Frigo et al., 2016), medicine (Bin et al., 2020; Tang et al., 1998), tourism (Loureiro et al., 2020), architecture and construction (Salleh et al., 2021; Hou et al., 2015; Behzadan et al., 2015; Beraldi et al., 2020; Chi et al., 2013) mechanical engineering, mechatronics (Stark et al.,2020; [12], Kučera et al., 2018) emergency management (Zhu and Li, 2021), etc. Number of works also deal with the application of these technologies in the prevention of damage to underground infrastructure facilities (Roberts et al., 2002; Schall et al., 2009; Schall et al., 2013; Jurado et al., 2017; Piroozfar et al., 2021; Behzadan and Kamat, 2009). The application of virtual reality in the detection and display of manholes, utility lines and other objects of utility line cadastre, is not practical, because it requires the use of one of the existing models of VR glasses (Figure 1a), which completely places the user in a virtual environment, without feeling objects from the environment. On the other hand, the concept of augmented reality requires loading the model via a mobile or tablet device and places the loaded model in the user's existing environment (Figure 1b). This way, the loaded model fits into the real (physical) environment, so that the user can move freely, view the model, move it, rotate it, scale it or read the dimensions of the model as needed.

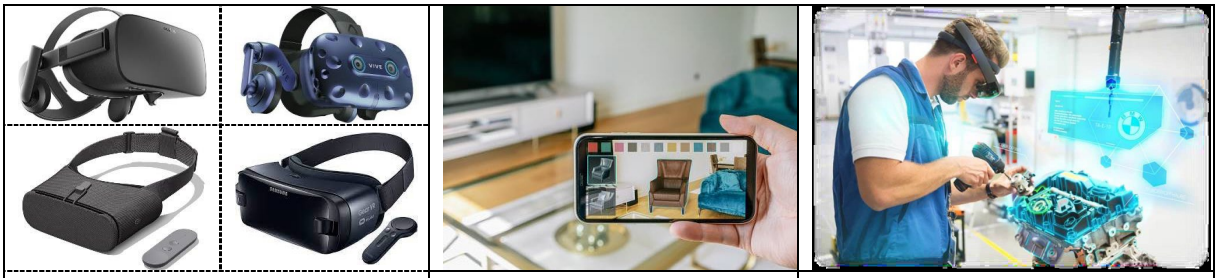


Figure 1. Different models of virtual reality glasses (a); display of the augmented reality model (b); equipment and application of mixed reality (c)

In addition to the concept of virtual and augmented reality, the term mixed reality (MR) was introduced in 1994, which represents a combination of virtual and augmented reality (Figure 1c). For this need, specialized glasses are also used, which "project" different models to the user depending on the needs. The display of different models and contents is most often done in an automated way, recognizing the appropriate images that are in the user's focus (Figure 1c).

Within this work, the concept of augmented reality is used to visualize different types of manholes, including their contents. Augmented reality makes it possible to fit a new object into the existing environment, as well as direct the user's movement along a defined path within complex objects. Augmented reality is a step closer to reality than virtual reality, because it does not simulate the entire environment, but supplements the real environment with the desired objects or information. Some of the additional advantages of augmented reality compared to virtual reality are reflected in the following:

- The user can manipulate the augmented reality model, without "losing the knowledge" of the environment in which he/she is.
- Creating an augmented reality model is simpler than developing a complete virtual environment.
- Augmented reality allows the user to view the inside of the manhole (without opening it), as well as the location and position of the underground lines.
- Models used in augmented reality can be created on the basis of CAD files from the utility network cadastre and visualized through appropriate mobile or tablet applications.

The contribution of this work is reflected in the development of FME models for different types of manholes with different complexity of manhole contents, as well as their application and display in an augmented reality environment. The main goal is a fast and modern way of displaying the content, shape, and texture of the manhole without subsequently opening the manhole cover in the field. This way the other utility objects can also be presented in augmented reality environment. The basic steps for developing and using the model are shown in the Table 1.

Phase 2 and Phase 6 will be explained in more detail in next sections.

Table 1. The phases for developing model for manholes

PHASE 1	**Acquisition**
• Gathering information about the location, position, shape, dimensions and content of the manhole (on terrain, from documentation, from CAD or shp files)	
PHASE 2	**Modeling**
• Manhole cover (circular/rectangular cover with appropriate texture and thickness) • Manhole frame (definition of dimensions, thickness, texture) - optional • Terrain around the manhole (adding appropriate texture, terrain dimensions, etc.) – optional • Manhole interior (utility lines; includes complex scenarios like fractures, valves; adding texture or matching color) • Bottom and walls of the manhole (depth, texture, dimensions)	
PHASE 3	**Testing**
• Overview of layers, textures, dimensions, mutual relationships etc.	
PHASE 4	**Creating a database**
• Storage of created models in the appropriate database	
PHASE 5	**Integration**
• Extending the already developed LADM based model for the utility network cadastre • Connecting the model with the existing algorithm for the untility network cadastre	
PHASE 6	**Visualization**
• Loading the appropriate model and displaying it in the space at the appropriate location	

3. DEVELOPMENT OF THE FME MODEL

The development of model to display manholes in some of the augmented reality applications was carried out using the FME software package. FME enables the integration of different input data, their transformation and data extraction in various formats for different fields of application. Data integration enables the combination and analysis of data across isolated segments at a detailed level. FME represents the combination of different input data formats, the extraction of the desired information as well as its combination with other data sources in order to export the data in the desired format or write it into the appropriate database. Initially, FME tools were developed for GIS and CAD data. Later the extensions for working with different DBMS, XML files, BIM models, but also virtual and augmented reality data were developed. Within this work, two models were created for the visualization of manholes:

- manholes with a circular cover and cylinder-shaped interior and
- manholes with a rectangular cover and a parallelepiped interior (Figure 2).

Both models consist of several units:

- creation of immediate surroundings on the surface including the manhole cover,
- the inside of the manhole including the shape, material and texture of the side walls as well as the bottom of the shaft,
- manhole contents in the form of pipes and cables with different diameters, depths and textures.

Figure 2 shows the developed FME model for a manhole with a rectangular cover.

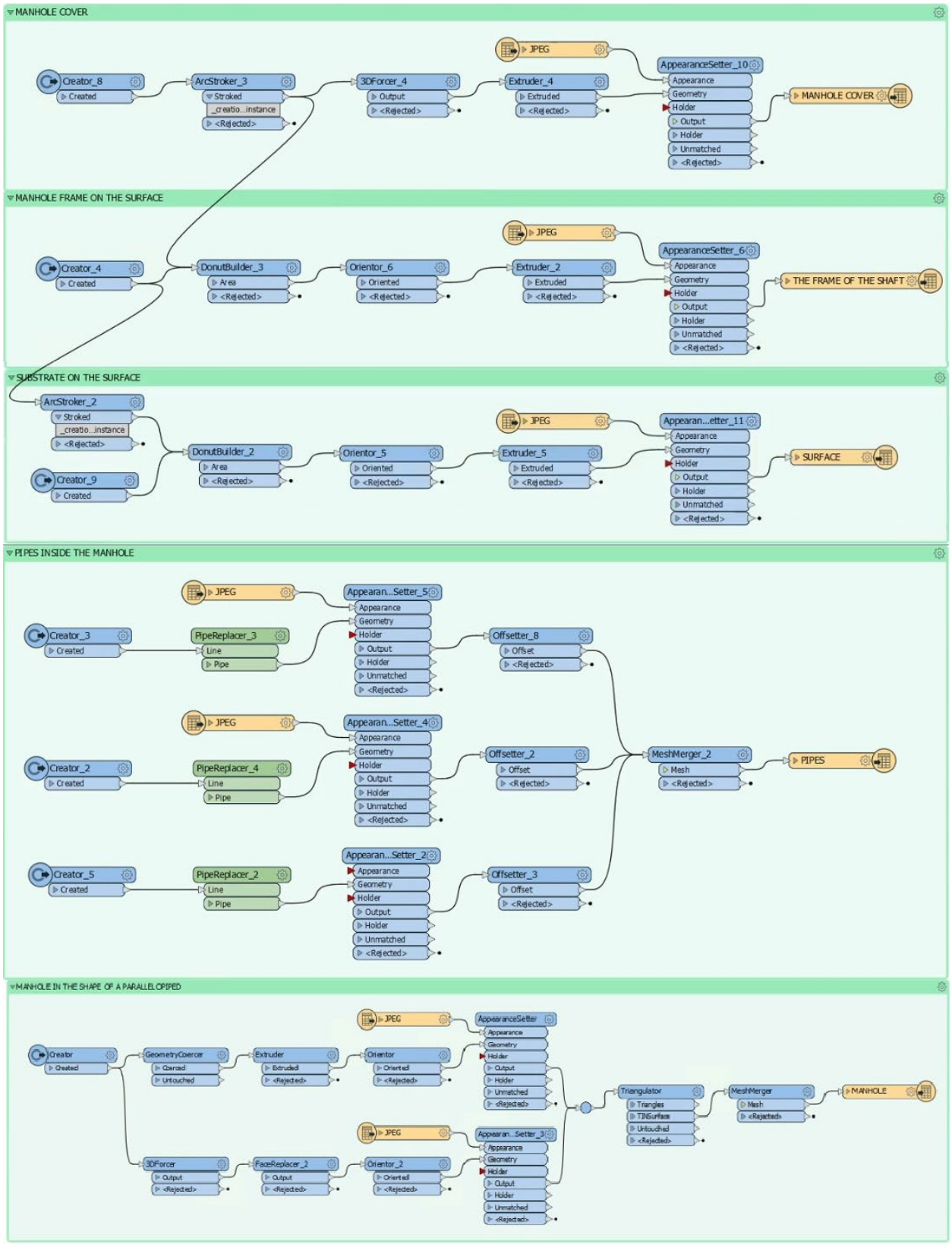


Figure 2. A model of a manhole with a rectangular cover and a parallelepiped interior

The model of a manhole is organized in five segments in order to be more readable.
Part 1 – Manhole cover. In this segment, a 75x75cm manhole cover was created. The manhole cover, 2 cm thick, is placed at the level of the terrain. The texture that was chosen for the appearance of the cover can be seen in Figure 3. Using the Creator transformer, a frame of the cover with appropriate dimensions is generated, which is then converted to a polygon using ArcStroker transformer. The Z coordinate of the manhole cover is defined with the 3DForcer transformer, after which the third dimension of the manhole cover (thickness) is defined using the Extruder transformer. It should be noted that it is necessary to define the Z coordinate in order for the Extruder transformer to be applied. In the final step of this segment, the appropriate texture of the manhole cover is assigned by applying the AppearanceSetter transformer.
Part 2 – Manhole frame on the surface. The second segment of the FME model includes the frame of the shaft, measuring 1.15x1.15 m, which is raised in relation to the ground level by 5 cm. The manhole cover dimensions are passed to this model segment to create the opening for the manhole cover. After creating a polygon (transformer Creator) of appropriate dimensions that defines the frame around the manhole cover, the polygon is cut at the place of the manhole cover using the DonutBuilder transformer. By applying the Orientor transformer, the orientation of the created polygon is defined. The thickness of the polygon is defined (Extruder transformer) and the appropriate texture (AppearanceSetter transformer) is added.
Part 3 – Substrate on the surface. The ground surface is created in the third segment of the model. It is first defined by a polygon measuring 4x4m, and then an opening is created on it, on which the manhole frame is placed. The thickness of the surface was set to 2 cm, and different textures were used to display the surface. In this segment, the same transformers as in part 2 were used, except that instead of the dimensions of the cover, the dimension of the manhole frame is used, as well as another texture.
Part 4 – Pipes inside the manhole. In this segment, the interior of the manhole was modeled. Three pipes of different orientations, diameters and depths have been added to the model, namely:

- at a depth of 1.2m, a pipe with a diameter of DN50 was placed,
- a pipe with a diameter of DN250 is located at a depth of 1.4m and
- a pipe with a diameter of DN500 is located at a depth of 2m.

First, all utility lines and cables are defined as line segments using the Transformer Creator. Next, the appropriate diameter is defined with the PipeReplacer transformer, after which the color/texture of the pipes or cables is added (AppearanceSetter transformer). The depth at which the utiity line is located is defined using the Offsetter transformer. Finally, all utility lines and cables inside the manhole are merged into one object using the MeshMerger transformer (for visualization in the form of a single layer).
Part 5 – Manhole in the shape of a parallelepiped. The last segment of the created model includes defining the dimensions of the inside of the manhole, its positioning in the model, as well as the texture of the walls and bottom of the manhole. The dimensions of the created manhole are 2x2x2.5m. A brick look was chosen for the texture of the side walls, while a water texture was chosen for the bottom. In the first step, a polygon of appropriate dimensions (transformer Creator) is defined. This polygon is used to define the bottom of the manhole as well as the side walls of the manhole. The polygon is then converted into a 3D object by adding the appropriate depth (transformer 3DForcer), after which using the FaceReplacer

transformer it keeps only the face of the object. After defining the orientation, the desired structure for the manhole bottom is added. Using the GeometryCoercer transformer, only the frame of the polygon is extracted to which the appropriate depth is added (Extruder transformer). This way, the side walls of the manhole are obtained. The walls are then oriented using the Orientor transformer, and the appropriate texture is added (AppearanceSetter transformer). In the final step, the bottom and side walls of the manhole are joined and converted into a TIN structure (transformer Triangulator), which is then combined with the MeshMerge transformer. An FME model for a manhole with a circular cover and cylinder-shaped interior was made in a similar way.

4. VISUALIZATION OF THE FME MODELS

The mobile application FME AR (FME Augmented Reality) was used to visualize the models developed through the FME software package. This app runs models saved in .fmear format and is available for download via Google Play or the Apple App Store. A model of the manholes with a circular and rectangular cover in surface view is shown in Figure 3a while the inside of the manhole is shown in Figure 3b. The number of different layers that can be included/excluded in the final model depends on the number of export segments contained in the final parts of the FME model. Figure 3a and Figure 3b show the different layers implemented through the developed models of manholes with a circular and rectangular cover, as well as a view of details from different angles.

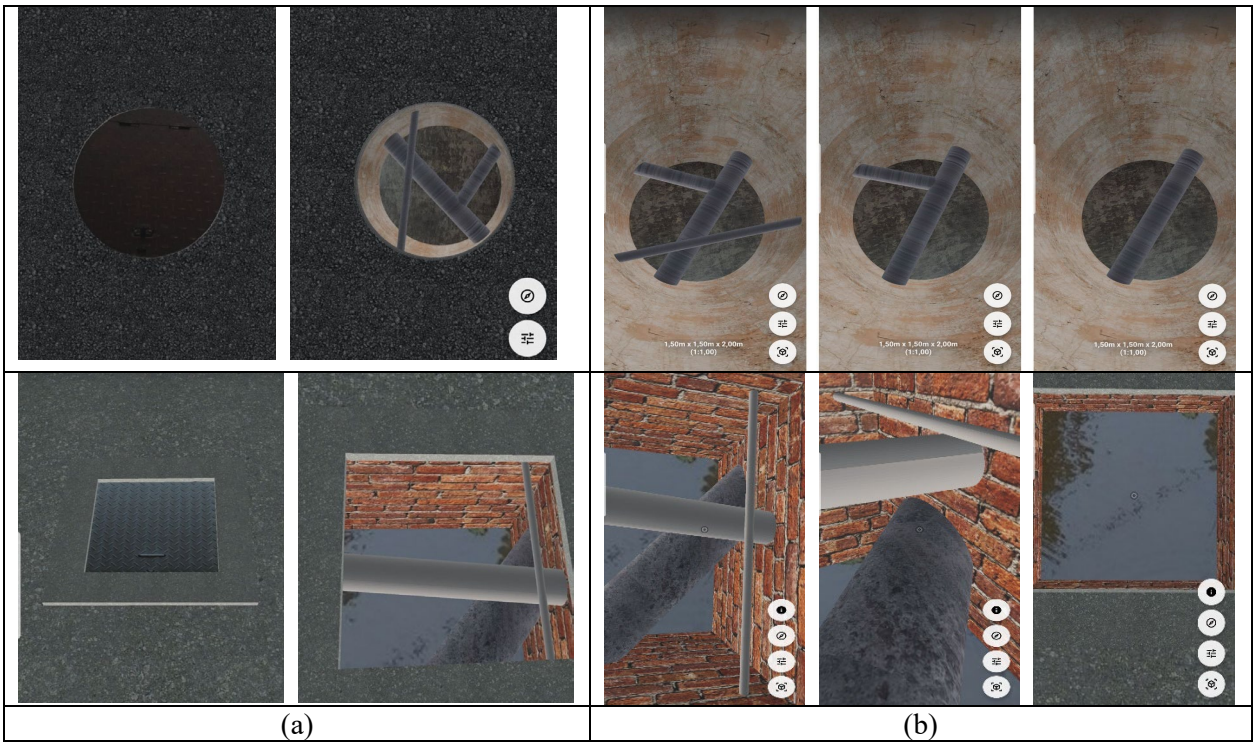


Figure 3. Visualization of manhole models with circular and rectangular covers including their content and display through different layers

5. EXTENDED LADM UTILITY NETWORK MODEL TO SUPPORT AR DATA

In the previous years, many LADM based country profiles have been proposed, among them for Serbia (Radulović, 2017). Serbian LADM profile is prooved to be compliat with the LADM on the level 2. Figure 4 shows the basic set of classes from Serbian LADM profile. Core classes of the profile are RS_SpatialUnit, RS_Party, RS_RRR and RS_BAUnit. The RS_SpatialUnit class describes spatial objects in the cadastre, including parcels, buildings, and parts of buildings, as well as utility lines and related objects. The country profile allows the joining of the real estate and utility network cadastre data as required by the Law (Official Gazette, 2009) by introducing the RS_LegalSpaceUtilityNetwork class. The class RS_Party represents right holders and RS_RRR holds data about rights and restrictions (mortgages, easements and notices). Class RS_BAUnit represents a basic administrative unit, which is a set of rights and restrictions of one real property so that the sum of shares is equal to one. In Serbian cadastre, basic administrative unit is equivalent to the real estate folio for parcels, buildings and part of buildings, as well as for utilities. The Law describes the legal aspects on utility lines the same way as for the real estate cadastre.

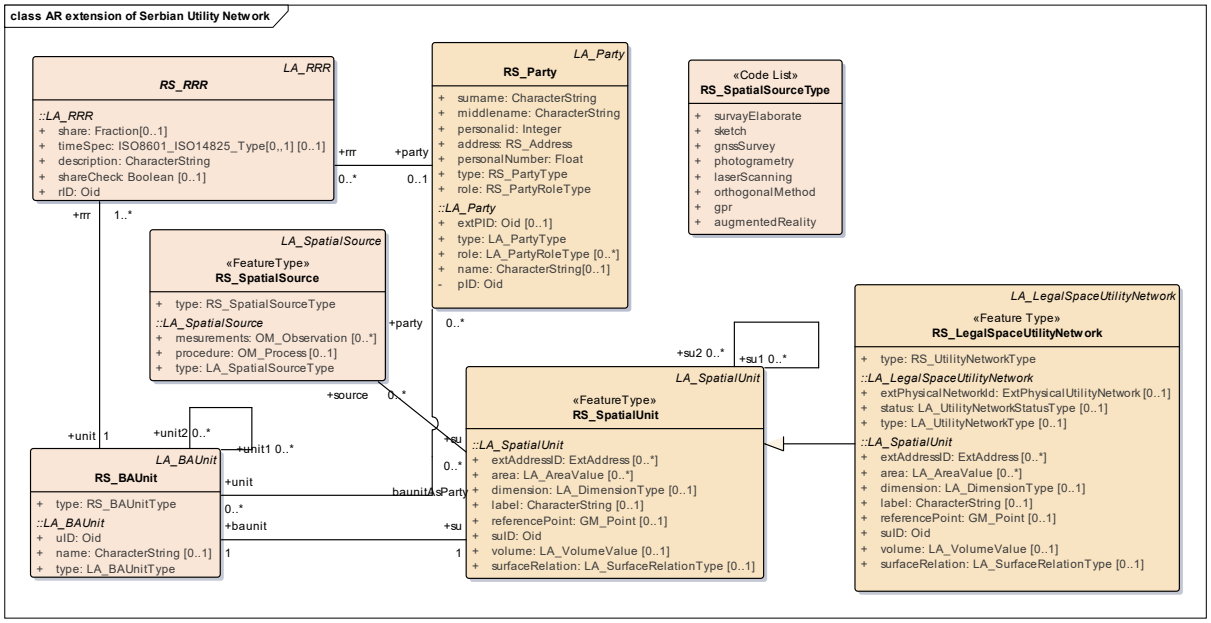


Figure 4. Extracted set of classes from Serbian LADM profile

There are seven type of utility networks: electricity, gas, water, heat, oil, sewerage and telecommunication network. In each of them utility lines can be seen as a link sets, intersection points can be seen as nodes and related facilities can be seen as objects. Therefore, the Serbian Utility Network Model is defined as shown on Figure 5. It contains three abstract classes that represent the network main elements: RS_Node, RS_LinkSet and RS_Objects, as well as number of code lists. The common attributes are stored in these classes for all types of utility networks. Furthermore, for each type of network a set of classes are derived from the Serbian Utility Network Model (Radulović, 2019).

The adjustments of the model for the augmented reality data can be made on the network model level. Since, the augmented reality models are new type of data source two code lists are expanded. The code list RS_SourceType (Figure 5) is expanded in order to indicate the source type for each type of the network elements. The code list RS_SpatialSourceType (Figure 4) is expanded in order to indicate the source type of the whole spatial element which can be sometimes consisted of more elements. For this purpose a class RS_GroupObject is introduced to support the models, like the ones presented in previous section, which consists of several utility lines, nodes and objects.

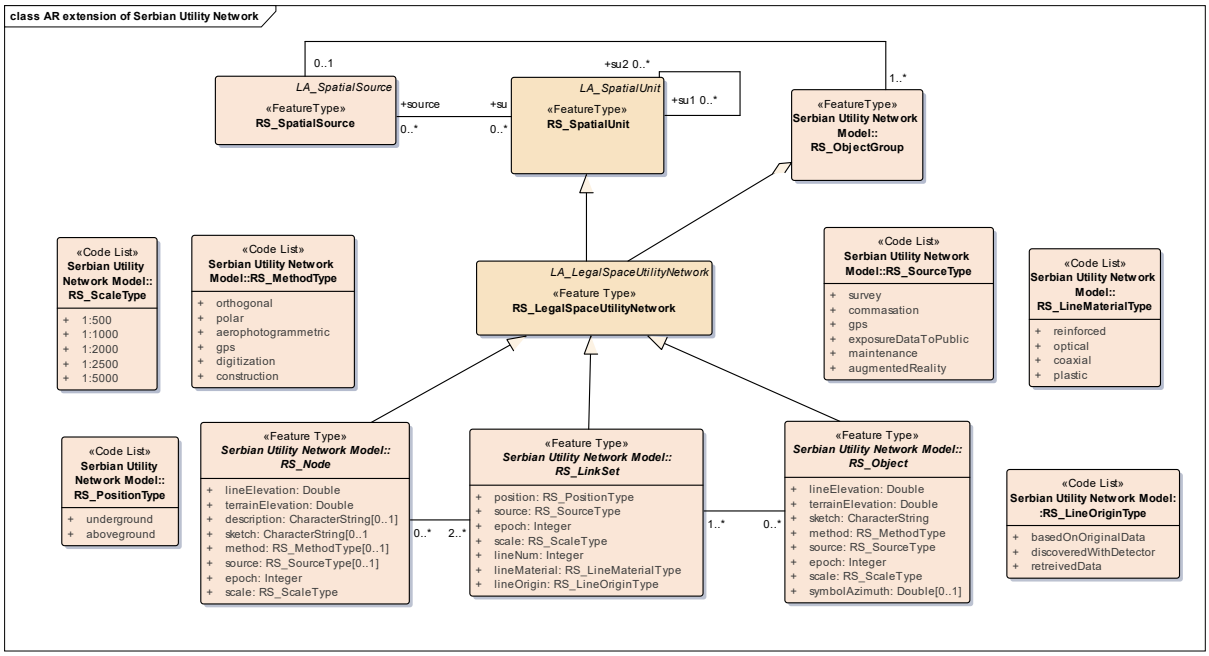


Figure 5. Extended Serbian Utility Network Model to support AR data

CONCLUSION

In this paper, a possibilities of using augmented reality data for better display of utility line data is analyzed. Two different manhole models were created: a manhole with a circular cover and a manhole with a rectangular cover with a parallelepiped interior. The models were created in the FME software package and displayed using the FME AR mobile application. The created models include a description of the concepts and development of the model through the FME environment, including all important parameters for underground infrastructure objects, such as: material, depth, diameter and orientation of underground lines/cables. The created models include the possibility of adding the texture of the ground surface, but also the walls and the bottom of the trench in which the underground lines/cables are placed. Based on the developed augmented reality models, it is concluded that a better impression about layout, mutual relationship, diameters and material of the lines, but also the texture and dimensions of the trench/shaft in which the lines are located, is obtained on the field.

In second part of the paper, an analysis of using augmented reality data as spatial source for utility network cadastre is analyzed. In order to achieve this, already developed LADM based utility network model for Serbia is extended with code lists and the class. Combining one or more models can allow user to see more utility line data.

In the future, similar FME models can be also developed for other types of utility objects. By using data from cadastral maps and measuring on the field, models can be produced quickly since the manholes usually have the standard dimensions. Partial automation can be achieved based on the depth of the pipes reaching the manhole and information about the orientation of the manhole, that can be provided from an orthophoto image.

Developed models can be used in the field when it is necessary to do see the spatial arrangements of the utility lines during the maintenance or placing new utility line. This way the possibilities of damaging the already placed utility lines will be reduced and the possible earth digging would be limited to a smaller area. Another use of such data can be seen in office conditions when it is necessary to do the overview of the data. Since the data in utility network cadastre in Serbia is 2D based, the third dimension would give better insight in data and thus possible better decisions.

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BIOGRAPHICAL NOTES

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Ph.D Aleksandar Ristić is a Full Professor in the Department of automation, geomatics and control systems and lecturer in underground utility detection by GPR and EML, geosensor networks and control systems in geomatics. His current research interests include development of innovative inspection procedures for GPR surveying of underground utilities in urban areas, and quantitative estimation of EM and physical properties from GPR data with development of advanced GPR data processing techniques. He participated in the project of development and implementation of first GPS permanent stations network in Serbia, in 2003. He published a number of papers in journals and scientific conferences proceedings related to GPR technology. Also, he is reviewer in several journals. He also participated in international projects (EUPOS Berlin, COST 1208). He has been project leader in a number of projects directly related to GPR applications and runs the laboratory for sub-terrestrial remote sensing.

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Is more always better?
Perceptions of property data visualization in 2D and 3D, in the context of Smart Communities and Smart Governance development

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Key words: 3D cadastre, 3D land administration, property data visualization, Smart Cities, Computer Aided Web Interview (CAWI)

SUMMARY

Throughout history, the cadastre has played roles such as ensuring citizen privileges and protecting the rights of landowners. It has evolved over time to include fiscal functions. The land administration system (LAS) has played a significant role in the management of land and property relations. Modern land administration systems aim to support sustainable decision-making and smart urban development.

Due to the complexity of existing and emerging buildings inadequately accounted for by traditional 2D cadastres, the need for a 3D cadastre has arisen. Additionally, global population growth and urbanisation have only accelerated the need for this concept.

In contrast, the 'City 5.0' paradigm focuses on citizen-centred urban planning, emphasising barrier-free access to public goods and services. Important aspects of a smart city include stability, healthcare, employment, housing and culture/education. 3D cadastres can play a key role in the realisation of smart cities by providing accurate and unambiguous data for urban planning. Additionally, they will improve the economy and society through the efficient use of both above- and below-ground space.

The aim of the study conducted by the authors was to find out how people from different backgrounds deal with the graphical representation of property data. A survey method called Computer Aided Web Interview (CAWI) was used to conduct the study. The questionnaire presented respondents with 2D and 3D cadastral visualisations in order to assess their perception. The analysis of the results obtained was based on the division of respondents according to their education (primary, lower secondary, basic vocational, secondary, higher or university education) and gender.

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1. INTRODUCTION

The cadastre has had an important role in everyone's life since ancient times. Property records primarily provided privileges such as citizenship. Over time, however, cadastral systems did not only have a recording function, but also a fiscal function and a function to protect the rights of landowners. The relationship between land and people has been developed over the years mainly through the Land Administration System (LAS) solution. Today, however, the world's focus is on developing modern land administration systems to support human decision-making and sustainable actions in space. The land cadastre is the basis for integrated land management systems, efficient property markets and the protection of property rights. The current approach to real estate is more complex than traditional definitions of land. This requires new concepts and definitions of real estate.

The complexity of already existing and emerging buildings required an adequate registration of the legal status, which was not provided by a 2D cadastre. In addition, the significant increase in the world's population and the migration of people from rural to urban areas were the reasons behind the concept of a 3D cadastre. The first workshop covering this topic took place in November 2001 in Delft. During this period cadastral agencies around the world were undergoing many changes in order to better prepare their systems to handle them in 3D. Despite much commitment and progress, no country has a true 3D cadastre.

A scale of changing colours or shades of grey is generally used to give the impression of distinguishing, for example, the height of the terrain. Man-made point, line or surface objects, on the other hand, are presented using conventionally adopted symbols. Depending on the scale of the study, these objects are presented with the true scale of the object (at large scales) or without it, if not possible (at small scales). All this also applies to the widely understood real estate, which in Polish conditions (and not only) are land parcels, buildings and premises (not visualised on traditional maps). Cartographic representations, regardless of the adopted reference system, are generally the vertical projection of the surface of the terrain onto the plane. In contrast, information on three-dimensional objects is conveyed through additional data visualised through appropriate referencing. Traditional two-dimensional visualisation still plays a significant role in terrain information. However, three-dimensional models in spatial visualisation may help to better understand the reality around us. It was not until 10 years later that both technical and organisational possibilities allowed the issue of 3D cadastre to develop significantly. The 3D registration of properties has thus become crucial for understanding the complexity of the built environment. It has proven to be a significant support for sustainable human action in space. It is envisaged that it can improve the process of land taxation, property security, real estate market operation and spatial planning.

According to European Union digital policy 'A smart city or community aims at the well-being of its inhabitants, businesses, visitors, organisations and administrators by offering digitally enabled services that contribute to a better quality of life. These smart services can help to better manage resources like energy or water, to monitor and reduce local traffic and pollution or in the work towards greener ways to light and heat buildings' (European Commission, 2023). The idea of this research is to make preliminary assessment if the visualisation in 3D of cadastral objects can contribute to the idea of smart community.

2. MATERIALS AND METHODS

The research was carried out using a survey method using a technique that is part of quantitative market research methodology, namely Computer Assisted Web Interviewing (CAWI). The survey presented two-dimensional and three-dimensional cadastral visualisations, and the respondents were people of different ages with various educational and occupational statuses. This allowed the authors to get an idea of how people with different backgrounds deal with the graphical representation of real estate data. The questionnaire concerns perception of information about real estates presented on figures with 2D and 3D situations.

The questionnaire consists of twenty three questions – ten questions concerns 2D situations, ten questions 3D situations, two questions evaluate the ways in which they presented property information and the last one is the metrics. Metrics, includes an additional nine questions relating to age, gender and contact with graphical representation of real estate data in 2D and 3D. All questions representing both 2D and 3D situation were divided into three categories. It was done after completing questionnaire during results elaboration. They are as follows:

a. Number of buildings perception,
b. Perception of the buildings' location in relation to the land parcels,
c. Perception of storeys – number and location.

Number of questions concerning corresponding situations is not always identical for 2D and 3D situations. There is four questions for category (a) for both situations, three questions for 2D situations and two questions for 3D situation for category (b). Correspondingly it is three and four questions for category (c). The results of the questionnaire were processed quantitatively and collated.

Visualisations depicting information about objects in two dimensions have been made in the EWMAPA programme. They represent typical, simple cadastral situations. This means that parcel boundaries appear in blue and vectorised buildings in red in the images. In addition to the graphic representation of the aforementioned objects, respondents could also find information such as the number of storeys, building type and parcel numbers. The questionnaire also included visualisations that showed real estate data in three dimensions. In these questions, respondents could only notice the presence of real estate boundaries and buildings presented in the same shade of grey. However, their boundaries were marked in

black. Apart from the aforementioned objects, there was no additional information in the visualisations apart from this graphic information. SketchUp software was used to create these objects in 3D. The situations depicted on them were created only for the purposes of the study.

The survey was completed by a total of 400 people. More than half of them, 210 to be precise (52.5%), were women. In addition to gender and age, the questionnaire also included a question about professional status, where respondents could choose between: pupil or student, employed, unemployed, pensioner or retired (Table 1). The majority of women were in the employed group (57.1%), while the smallest number were students (4.3%). As for men, the same number were employed (70.5%) and the least were unemployed (3.2%). The next question in the metric was what education the respondents had. This time the answers were: primary, lower secondary, basic vocational, secondary and higher or university education. Again, as can be seen in Table 2, most women had secondary education and only 4 of them primary education. In men, the same majority had secondary education and only one had lower secondary education.

Table 1. Occupational status of respondents in percent

	student	employed	unemployed	pensioner
women	4.3%	57.1%	9.0%	29.5%
men	4.2%	70.5%	3.2%	22.1%

Table 2. Data on the education of respondents given as a percentage

	primary	lower secondary	vocational	secondary	higher or university
women	1.9%	0.0%	8.1%	48.6%	41.4%
men	1.1%	0.5%	10.5%	48.4%	39.5%

3. RESULTS

Results obtained from the questionnaire were elaborated with division on 2D data perception and 3D data perception and presented accordingly.

3.1 **Perception of 2D real estate data**

3.1.1 Number of buildings perception

Four questions from the questionnaire for situation 2D were related to the number of buildings seen by respondents on individual parcels. The average score of correct answers obtained for these questions was 55.5%. The analysis of the results was based on dividing the respondents by their education level (primary, lower secondary, vocational, secondary, higher or university) and gender. The first conclusion is that men performed better with an average of 60.0% correct answers. Women, on the other hand, achieved a slightly lower score of 46.8%. Quantitatively, the least numerous groups were those with primary and lower secondary education. They numbered 6 (4 women and 2 men) and 1 person (a man), respectively. As a result, there are extremely high or low percentages of correct answers.

Further analysing women's responses, the group with vocational education had the highest number of correctly solved tasks. However, the other groups did not deviate significantly from this result. Most of them, as seen in Table 3, except for those with primary education, achieved above 40% correct answers. Among men, excluding the two groups mentioned above, those with higher education performed the best, while those with vocational education performed the worst. The results are presented in Table 3.

Table 3. Percentages for correct and incorrect answers to questions about the number of buildings perception in 2D

	ca-pe	ia-pe	ca-lse	ia-lse	ca-bve	ia-bve	ca-se	ia-se	ca-ue	ia-ue
women	37.5%	62.5%	-	-	54.4%	45.6%	45.1%	54.9%	49.4%	50.6%
men	75.0%	25.0%	75.0%	25.0%	47.5%	52.5%	48.4%	51.6%	54.3%	45.7%

Legenda:
ca-pe - correct answer primary education
ia-pe - incorrect answer primary education
ca-lse - correct answer lower secondary education
ia-lse - incorrect answer lower secondary education
ca-bve - correct answer basic vocational education
ia-bve - incorrect answer basic vocational education
ca-se - correct answer secondary education
ia-se - incorrect answer secondary education
ca-ue - correct answer university education
ia-ue - incorrect answer university education

3.1.2 Perception of the buildings' location in relation to the land parcels

The next three questions in the survey were related to the category of perceiving buildings in relation to their location on parcels. Such questions posed significantly more difficulties for respondents than the previous category. Analysing the answers based on education, none of the groups achieved a 50% or higher rate of correct answers. This result may be related to situations where there is a separate parcel beneath the building, and a reference to its number can be found there. The lowest score in responses for this category was achieved by women with secondary education (10.3%). However, the results for other groups of both women and men ranged between 35% and 45% correct answers, as can be seen in Table 4. Legend below Table 3.

Table 4. Percentage of correct and incorrect answers to questions on perception of the buildings' location in relation to land parcels in 2D

	ca-pe	ia-pe	ca-lse	ia-lse	ca-be	ia-bve	ca-se	ia-se	ca-ue	ia-ue
women	33.3%	66.7%	-	-	35.3%	64.7%	10.3%	89.7%	43.7%	56.3%
men	50.0%	50.0%	0.0%	100.0%	35.6%	64.4%	42.3%	57.7%	45.5%	54.5%

3.1.3 Perception of storeys – number and location

The last category of questions for situation 2D was the perception of floors, specifically their quantity and location. When comparing all three categories of questions, this one performed the best in terms of percentage. Respondents answered at a level of 59-70% correct answers

(Table 5). The exception was the groups with primary and lower secondary education, where one person decides whether to consider the result as positive or negative. In the first of these groups, women achieved a score of 25% correct answers, while men slightly more with 33.3%. In the case of men in the second group, the results significantly raised the average due to achieving 100% correct answers to the question. These results suggest that the red colour, used to mark buildings, their floors, and their purpose, is much more easily comprehensible to the respondents' eyes. Legend below Table 3.

Table 5. Percentage of correct and incorrect answers to questions on perception of storeys – number and location in 2D

	ca-pe	ia-pe	ca-lse	ia-lse	ca-bve	ia-bve	ca-se	ia-se	ca-ue	ia-ue
women	25.0%	75.0%	-	-	70.6%	29.4%	69.6%	30.4%	65.5%	34.5%
men	33.3%	66.7%	100.0%	0.0%	70.0%	30.0%	59.8%	40.2%	59.3%	40.7%

3.2 **Perception of 3D real estate data**

3.2.1. Number of buildings perception

Moving on to questions using three-dimensional visualization, four of them were related to the number of buildings on the specified parcel. Analysing the Table 6, it's noticeable that the average score of correct answers for both genders is above 70%. Comparing the results of this category in 2D and 3D, it can be concluded that visualizations enhanced by an additional dimension make it easier for respondents to identify the correct answers. These differences range between 10% and 30%. Delving into the results, it was observed that women performed best in questions about the number of buildings on the parcel among those with vocational education. In contrast, among men, those with secondary education performed best. A completely opposite situation occurred in the case of the least well-solved questions. Legend below Table 3.

Table 6. Percentages for correct and incorrect answers to questions about the number of buildings perception in 3D

	ca-pe	ia-pe	ca-lse	ia-lse	ca-bve	ia-bve	ca-se	ia-se	ca-ue	ia-ue
women	56.3%	43.8%	-	-	76.5%	23.5%	72.5%	27.5%	74.3%	25.7%
men	87.5%	12.5%	100.0%	0.0%	75.0%	25.0%	79.3%	20.7%	78.7%	21.3%

3.2.2. Perception of the buildings' location in relation to the land parcels

Perceiving the number and location of floors for questions with 3D visualizations was generally quite well recognized at a level of over 50%. The only exceptions were women with higher education and men with primary education. Analysing the responses for this category in two spatial situations, the conclusion was drawn that respondents provided more correct answers for questions with two-dimensional images. Referring to Table 7, women from the vocational education group indicated the most correct answers, and among men, it was the group with secondary education. Legend below Table 3.

Table 7. Percentage of correct and incorrect answers to questions on perception of the buildings' location in relation to land parcels in 3D

	ca-pe	ia-pe	ca-lse	ia-lse	ca-be	ia-bve	ca-se	ia-se	ca-ue	ia-ue
women	37.5%	62.5%	-	-	23.5%	76.5%	11.8%	88.2%	6.9%	93.1%
men	50.0%	50.0%	0.0%	100.0%	5.0%	95.0%	13.0%	87.0%	10.7%	89.1%

3.2.3. Perception of storeys – number and location

The category of questions related to perceiving buildings in 3D in relation to parcels achieved very comparable results to 2D questions. Visualizations in which it was clearly visible that a building was located on a larger number of parcels were better solved by respondents. However, in situations where there is a separate parcel beneath the building, and this time there is no reference, as in the case of 2D visualizations, it posed significantly more problems. The best results, except for the group with primary education in both genders, were achieved by women with vocational education (Table 8) and men with secondary education. On the other hand, people with higher education performed the worst. Legend below Table 3.

Table 8. Percentage of correct and incorrect answers to questions on perception of the buildings' location in relation to land parcels in 3D

	ca-pe	ia-pe	ca-lse	ia-lse	ca-bve	ia-bve	ca-se	ia-se	ca-ue	ia-ue
women	50.0%	50.0%	-	-	70.6%	29.4%	57.2%	42.8%	47.9%	52.1%
men	33.3%	66.7%	66.7%	33.3%	51.7%	48.3%	59.8%	40.2%	53.8%	46.2%

4. SMART COMMUNITIES AND SMART GOVERNMENT DEVELOPMENT IN THE CONTEXT OF OBTAINED RESULTS

The "City 5.0" paradigm is a new concept for city design, focusing on citizen-centric urban planning. This approach is defined as a market that connects providers of public goods and services with citizens as consumers of these services (Becker et al., 2023). One of the key elements of this paradigm is ensuring people's access to various public goods, such as infrastructure, healthcare, and education without barriers and exclusions.

Additionally, five different categories of vitality in a smart city have been discussed, including stability, healthcare and social services, employment and the economy, housing and environmental infrastructure, and culture and education. Each of these categories is crucial for ensuring the well-being of city residents (Becker et al., 2023).

The category of infrastructure, housing, and the environment pertains to the infrastructural aspects of smart cities that take into account their impact on the environment, such as affordable housing. This requires collaboration between academics, professionals, public administration, and citizens. The outcome of this relationship is effective management of constraints to shape City 5.0. The introduction of technological solutions is essential to improve this collaboration and manage both real and perceived constraints.

In summary, City 5.0 places citizens at the centre of future city design, emphasizing the elimination of constraints and ensuring the vitality of various aspects of life in smart cities. This approach can lead to more just, sustainable, and accessible cities that enhance the quality of life for citizens (Becker et al., 2023).

The growing urban population naturally brings about increased social, environmental, and economic challenges. These factors have not only led to the need for the development of smart cities but also for a 3D cadastre. Utilizing space both above and below ground helps

better organize urban areas to improve residents' lives. Three-dimensional information about property ownership and land can serve as a basis for effectively planning healthy and productive smart cities.

A 3D cadastre can provide accurate, authoritative, and unambiguous information to understand the urban structure (Rajabifard 2014). It can thus be used to create smart cities, both of which work toward the development of the economy and society. In many countries, 3D properties, such as apartments in buildings, are registered, but displaying them on traditional 2D cadastral maps is practically impossible. The solution to this problem lies in transitioning from a traditional 2D map-based approach to registering spatial units. However, the involvement of potential users is crucial in research to address various perception issues and meet citizen expectations.

5. DISCUSSION AND CONCLUSSIONS

In the category of questions regarding the perception of building locations in relation to parcels, respondents fared significantly better with 2D visualizations than with 3D ones. Looking at the percentage values of correct answers, these questions posed the most significant challenge to them. This could have been due to the fact that in the images depicting two-dimensional objects beneath the building, separate parcels could exist. These were marked on maps with blue references. Additionally, the use of the same colour for parcel boundaries could have been confusing. In the 3D visualizations, there were no references, and due to the significant colour differences between volumetric objects and their boundaries, these questions still posed the most significant challenge to respondents. In this case, men performed slightly better than women.

3D visualizations in questions about the number of buildings on specifically indicated parcels received significantly more correct answers than in 2D scenarios. Summing up all the percentage values, these were the questions that were best solved, with men outperforming women. In three-dimensional images, there were no additional distractors like the number of floors or the purpose of the building. However, the red colour used to indicate this information in 2D visualizations was distinctly different from the parcels. Despite this, the amount of information may have been confusing for respondents.

The last category of questions concerned the number and location of floors. This time, two-dimensional images were easier to recognize than their three-dimensional counterparts. This result could have been influenced by the clearly presented number of floors in the 2D visualizations. However, in 3D, without any additional information, respondents might have had difficulty identifying which building had more floors.

Furthermore, when comparing groups of respondents based on their education, women with vocational education performed best. As for men, those with secondary and higher education excelled.

Analysing a study conducted in 2015 (Wang 2015), which focused on examining how visual variables used to represent 3D environments influence a respondent's perception, the authors compared the results of this experiment with the usability of the same variables in the case of 2D visualizations. The conclusion drawn was that there was almost no noticeable difference in the effectiveness of colour saturation and texture.

Interpreting the results of studies conducted by the authors and similar research, one can conclude that it would be valuable to conduct a survey on the same research group, incorporating 3D real estate visualizations with various visual variables. This could be useful in expanding our understanding of user needs.

6. FURTHER WORKS

Following results presented in the paper, it is planned in the next step to elaborate results more precisely. It means not only in the category correct /incorrect but with analysing all replies. For example, when we have possible replies 0/1/2/3 buildings on the parcel and the proper answer is 2, it seems interesting what percentage of people choose other replies correspondingly (and why). The next step is the research of understanding rights to real estates in 3D on the same or similar group of respondents.

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BIOGRAPHICAL NOTES

Kornelia Grzelka obtained BSc in geodesy, surveying and cartography at the Faculty of Geo-Data Science, Geodesy, and Environmental Engineering, AGH University in 2020 and MSc in land management and cadastre at the same faculty in 2022. She started doctoral studies in October 2022 at AGH University of Krakow. Her interests are related to the 3D cadastre, 3D land administration, land management and GIS.

Jarosław Bydłosz obtained PhD at the Faculty of Mining Surveying and Environmental Engineering, AGH University of Science and Technology in Krakow, Poland, in 1997. He has been a faculty member since 2001. Jarosław Bydłosz obtained postdoctoral degree (habilitation) in June 2016. His scope of interests are Geographic Information Systems, cadastre and standardization. The recent activities concern 3D cadastre and issues concerning ISO 19152 “Land Administration Domain Model”. Presently, he works as an associate professor at the Department of Photogrammetry, Environmental Remote Sensing and Spatial Engineering, AGH University of Krakow.

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Digital Transformation of Land Administration Systems – the Next Step toward 3D Land Administration

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Key words: digital transformation, 3D Land Administration, LADM, 3D cadastre

SUMMARY

Introducing interoperability among spatial datasets and registers is one of the key drivers for optimizing public administration, starting from the simple automation of existing processes, to the overall transformation of the system, and the construction of modern user-oriented services. An additional incentive for such a transformation, in the European context, was the foreseeable need for interoperability between the national systems of registers and the European Union (EU) registers, and potentially in the future with other registers worldwide. A key prerequisite for the realization of interoperability is digitalization. Digitalization is the most important step towards the development of an effective 3D Land administration.

LADM country profiles integrate the legal and institutional context governing Rights, Restrictions and Responsibilities (RRRs) with the desired Land Administration Systems' (LASs) advancements. A significant number of countries have developed LADM-based country profiles. Experiences from these developments are in the direction of integrated Land Administration, which the LADM data standard provides, with a vision for the future and can serve as good practice for the countries.

This paper compares the digital transformation of the land administration in two vastly different case studies, in one EU country (Croatia) and in one Caribbean country (Trinidad and Tobago). A Comparison of these two land administration systems and their different tracks toward the development of a 3D land administration system that would address their differing social and economic needs within their individual resource and skill capacities was investigated in this paper.

It was found, after comparison, that the step by step process to further and develop from the existing status to a 3D cadastre that is LADM compliant is differentiated according to the needs, capacities, and resources available in each of the countries. Countries would do well to decide on their individual social and economic needs and capacities prior to embarking on a step by step process toward 3D land administration.

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1. INTRODUCTION

This paper describes and discusses the digital transformation of two different countries to compare how their processes fit their perceived priority needs and capacities. Croatia, a European country with access to developed technology and standards, has set out on the transformation of the most important parts of the Croatian land administration system. Connecting the joint information system of land registry and cadastre, Digital Geodetic Report System, Utility Cadastre System, Digital Archive System, Register of Spatial Units, National Infrastructure of Spatial Data with each other and with other public administration systems, has made a significant step forward in providing services to all entities as well as citizens, and made way for further modernization of LAS. A step forward to the 3D Land Administration in Croatia is the creation of a Building Cadastre, which is one of the more recent activities of the Croatian land administration as a new part of the real property register. Such a register should serve as a transitional register towards the establishment of a 3D cadastre.

Trinidad and Tobago, conversely, has more fundamental land tenure needs to satisfy, and fewer resources and capacities in its land administration system. The land administration system in Trinidad and Tobago is comprised of the cadastre, maintained by the Surveys and Mapping Division, the separate title registration, maintained by the Land Registry, the property valuation roll, maintained by the Commissioner of Valuations' office, and the land use datasets, maintained by the Town and Country Planning Division. These are all separate institutions with datasets that are not integrated or interoperable. The cadastre has, since 2000, been digitized but the data has not been able to be maintained current, nor to be comprehensive, because of the lack of sufficient human and financial resources. Cadastral maps for new parcel surveys and subdivisions are not incorporated into the database as readily as they should be. The cadastral maps are accessible online as scanned documents for free. The title documents at the Land Registry are digital, as the institution has recently completed a major project to digitize the title documents after the deeds had been digitized. The data in the form of scanned pdfs are accessible online for a fee. The property valuation roll is digital and reportedly contains some 400,000 residential properties but is not publicly accessible. The land use database is not digitized, nor accessible to the public. None of these datasets accommodate 3D data although the need for visualizing ownership, value and use in 3D is necessary for the relatively densely populated country where land and space are at a premium. There have been some investigations and discussions on the need for and the possibility of developing an LADM compliant system (Griffith-Charles and Edwards 2014; Griffith-Charles et al 2018). However, these would take a long time in implementation.

These two countries are on different paths toward 3D cadastre development as they have some similarities but different needs, resources, and capacities. This paper compares the steps taken with the needs, resources and capacities to determine how a country can align its processes to the 3D cadastre within its own environment.

2. DIGITAL TRANSFORMATION OF LAND ADMINISTRATION

The force of rapid developments in digital technologies and systems places imperatives upon managers of land administration systems to take advantage of the developments and to digitally transform. These transformations can assist land offices to provide more efficient services where land markets, legal environments and economic conditions are favourable, since digitally improved and modern land administration systems more easily support sustainable development goals (Kusmiarto et al 2021; Kalogianni et al., 2021). However, a country should have priority areas for development where the expenditure and direction of resources would be most effective.

According to FAO, UNECE and FIG (2022), when the spread of the COVID-19 virus became a pandemic, "many land administration organizations were already well equipped for the new normal, adapting to working at-distance, handling service spikes, responding swiftly to changing customer needs, and delivering novel data analytics services". FAO, UNECE and FIG (2022) also noted that many of these organisations operated in legal environments that supported quick adaptation of digital services to contemporary circumstances, with some of them even realising financial benefits therefrom. It was further noted that, while these organisations were able to cope with, and even benefit from, the situation, issues related to digital exclusion, data quality, standards, staff capacity, customer awareness, and partner collaboration became apparent. The authors also postulated that digital transformation of land administration systems and organisations is the *new normal*, and that this presents opportunities to improve services, create new services, and expand their client markets.

However, internationally, land administration organisations face various administrative, legal and technical challenges (Gebrihet and Pillay 2021; Kusmiarto et al. 202; Kilpin et al. 2023). The following sections describe the land administration needs of Croatia as well as Trinidad and Tobago, and how these needs have driven the process of digitising the cadastral data over time.

2.1 **Digital transformation in Croatia**

The cadastral map is the basis of Croatian land administration system. Urban planning, agriculture, construction, citizens, entrepreneurs use cadastral maps every day. The most important part of the Croatian Land Administration digital transformation is the digitisation of the analogue cadastral maps. The project to digitise the cadastral maps for the area of the City of Zagreb started in 1991 (Lipovšćak and Šurina, 1995). Other cities and municipalities developed/converted their cadastral maps in the first decade of the 21st century. The priority area for the digitisation process was therefore the more populous cities prior to continuing on the suburban and rural areas. This methodology, however, left many in the rural communities

lacking in secure tenure as the cadastral maps are still out of date and not reflective of the actual situation on the ground.

2.2 **Digital transformation in Trinidad and Tobago**

Digitisation of the various different, separated datasets has been ongoing for many years. In 1994 the reflying and photogrammetric mapping of the entire country led to the first digital topographic database, completed in 2000. It was intended that this digital topographic database would be the base layer for a digital cadastre. The existing analogue cadastral index was digitised in 2005 but was significantly mismatched to the topographic layer as well as having large voids and gaps of missing data. The purpose of this digitisation programme was to support self-sufficiency in food production so the thrust was to focus on agricultural parcels that could be allocated for this purpose. In the 1990s and 2000s, significant levels of global aid funding was devoted to developing cadastres for food self-sufficiency and then for establishing land markets as a reaction to globalisation imperatives. The programmes in Trinidad and Tobago therefore followed this trend. Figure 1 shows the original analogue cadastral index and an extract from the digitised version.

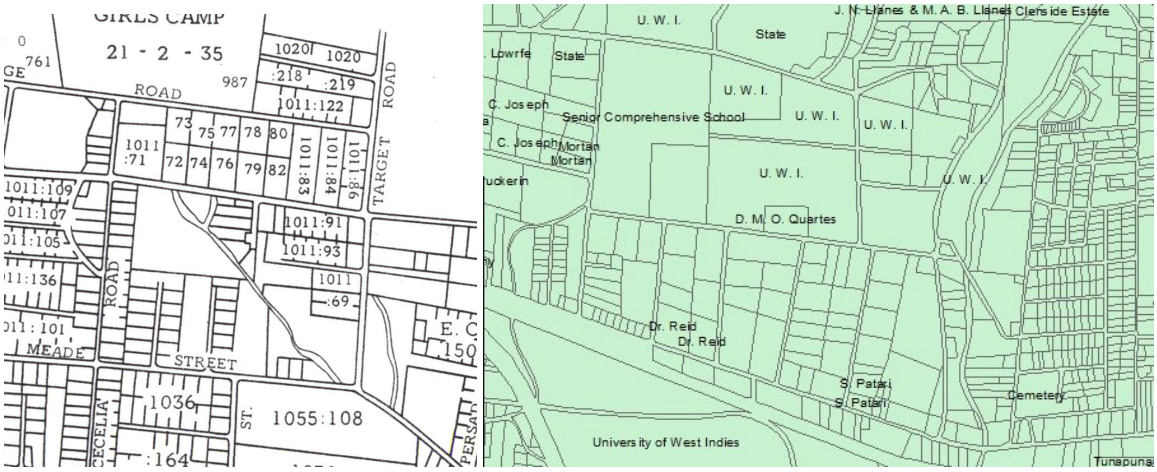


Figure 1. Paper index and early digitised index

As a result of the considerable mismatch between the datasets of the digital cadastral index and the digital topographic data, it was decided to acquire imagery at higher resolution in 2014 on which to overlay individual cadastral parcel survey data. Since cadastral surveys are not legally required to be coordinated in Trinidad and Tobago, the parcels were individually overlaid visually on the imagery. The more recent imagery has a resolution of 12.5cm so this is adequate for cadastral index purposes. The authoritative legal document is the survey plan signed by the licensed land surveyor. Figure 2 shows the imagery with the cadastral index outlines overlaid. This procedure, however, still left many gaps where surveys have not been done, long standing occupation is not legally recognised, or there is insufficient human resource to update the cadastre continuously as surveys are performed. At last count some 60,000 parcel plans remain out of the system but the larger issue is the insecure tenure that this represents.



Figure 2. Current digital cadastral index with attribute data displayed

3. 3D LAND ADMINISTRATION DATA

The limited advances in full 3D cadastres implementations throughout the world might be explained by the fact that the implementation of a 3D cadastre requires close collaboration between legal and technical experts in an empirical environment to understand the impact of each other's domain (Stoter et al. 2012). After more than two decades of using the term 3D cadastre in the world's academic and professional surveyors/cadastral circles, the current term "3D land Administration" is considered to be more apt as the multi-purpose use of the cadastral map only has been superseded by efforts to develop the whole integrated system of ownership, value, and use data . The term 'land' should be interpreted in the broad sense, also including water bodies (rivers, lakes, seas, oceans) and spaces above and below the surface, that is, air space and subsurface spaces. Land administration comprises an extensive range of systems and processes to administer: Land Tenure, Land Value, Land Use and Land Development, which are interrelated and influence each other (Kalogianni et al. 2020).

3.1 **3D Land Administration data in Croatia**

In the Republic of Croatia, there are a few sets of 3D Land Administration data available in the practice. The biggest part of Croatian 3D Land Administration are buildings and other structures. The buildings usually consist of many units of use of real properties. Currently in Croatia, buildings are registered in the land book based on the information delivered from the cadastral office. The cadastral office receives geodetic reports from licensed private surveyors usually in digital form. This information is authoritative. Ownership of a unit of use of real property (e.g. an apartment or an office space) is formed through the registration in the land book. Such unit of use may be registered if they constitute independent units of use (Vučić et al. 2013). Unit of use of real properties may include balconies, terraces, basements, and attics, under the condition that they serve exclusively a single unit of use. Land book registration of the units of use is not possible without the partition of real property procedure. LA_BAUnit consists of one or more LA_LegalSpaceBuildngUnits as one real property object with its own

RRR attached. The same procedure is commonly used in the land registry to formally consolidate land which was often publicly owned with buildings constructed on this land. The building complex first needs to be subdivided into multiple LA_LegalSpaceBuildingUnits, which can be used to form the LA_BAUnits to be registered in the Land book (adding the RRRs). Fair relationship in financing the maintenance of a building is furthermore made possible by establishing ratios of each party's ownership in the real property and each party's proportional share in the shared ownership of common parts.

The completely digitized and easily accessible Croatian land administration made a big step forward in 2020 by improving the accessibility of the service through the site www.katastar.hr with the possibility of locating oneself via smartphones and tablets. Later in 2022, that service was replaced and further improved by the joint One Stop Shop service available online (https://oss.uredjenazemlja.hr) of the State Geodetic Administration and the Ministry of Justice, also with the possibility of locating via GNSS technology embedded in smartphones and tablets (Figure 3). In a short period of time, it has become widely used by individuals and legal entities in many spheres of life, mostly in real estate-related business.



Figure 3. Building in Zagreb (Trnjanska street 63) view from cadastral parcel number 3697 cadastral municipality Trnje (Google street view)

The aforementioned service has the ability to display the Google street view service according to the given location, for all areas of the Republic of Croatia covered by the Google street view service. While Google street view only provides a 2D view of locations, the free Google Earth service provides a 3D view for urban areas (Figure 4) of the Republic of Croatia that can be used for many purposes before the official cadastral data begins to be collected and disseminated in 3D format.



Figure 4. Building in Zagreb (Trnjanska street 63) 3D view from Google Earth service

Buildings and other structures are registered in the cadastre with the following attributes: location (2D coordinates), area, intended building use, building name, and house number. A land register takes over two-dimensional data on real property from the cadastre. Real property may be further divided into common and particular parts, and registered in the land register based on the report on the particular part of the real property. Data on buildings are transcribed into land books based on the data delivered to the land register by the cadastral office. Ownership of a particular part of property (apartment or office space) is realized through registration in a land register. These particular parts may be registered if they make independent units of use. Particular parts may include balconies, terraces, basements, and attics, under the strict condition that they exclusively serve a single particular part and that they are clearly separated from other real property parts (Vučić et al. 2017).

On the State Geodetic Administration Geoportal three towns in Croatia (Sisak, Petrinja and Glina) have 3D representation of houses and buildings. The reason why only three towns (of 127 towns) have 3D graphical representation is the earthquake. The earthquake near Petrinja occurred on 29th December 2020 at 12:20 CET and had a level VIII of intensity on the Mercalli scale or a magnitude of 6.4 on the Richter scale. It was preceded by several minor earthquakes but also an earthquake with a magnitude of 5.2 on the Richter scale on the previous day. The earthquake caused casualties and huge material damage in Petrinja, but also in the nearby cities of Glina, Sisak and Zagreb. Seven people died and at least 26 others were injured, six of whom sustained serious injuries (Vučić et al. 2022). The next figure is the 3D representation of a few buildings in the City of Sisak – data captured by drone, after abovementioned earthquake (Figure 5).



Figure 5. The gymnasium building and the cadastre building in Sisak, 3D objects on the Geoportal of the State Geodetic Administration of the Republic of Croatia (source: URL 1)

In the last quarter of 2020 the State Geodetic Administration of the Republic of Croatia has started the procurement of geoinformatics services for the needs of establishing a Building Register in the pilot area in Varaždin county. These services include the development of a methodology for collecting and processing data on buildings and the development of a multipurpose data model that will consist at least of the graphic basis of the Building Register, a set of graphic data and a set of alphanumeric data. Based on the approach from this project, it is necessary to perform mass data collection and geoinformatics processing of data on all buildings in the pilot area in Varaždin county (Building Register project public procurement notice). The database should be established in order to provide integrated storage for alphanumeric and graphical (spatial) data on buildings. Processing of collected data, primarily topographical in nature, will be combined with data from other official records in order to build a more complete 3D model of buildings. During the integration of collected data with already available data from official registers, the following registers will be primarily taken in the consideration: Joint land book and Cadastre Information System (real property cadastre/land cadastre data and land book data), the Address Register and local government units' databases. Local government units' databases contain useful information about area, number of floors and real owner of real property and/or unit of use, but their databases are usually in MS Excel format or in better case in some custom made application.

Implementation of the Building Register project in the Republic of Croatia, as a new part of the real property register, is essential for the establishment of a unique register of buildings. This register will strengthen the legal security of owners and investors, contribute to the

dynamics and transparency of business processes in banks, insurance, housing policy, spatial planning and construction, enable a better overview of residence registration and building management, and ensure a simpler population census procedure (URL 2).

A significant and concrete step towards the 3D cadastre was made during the year 2022 for the needs of the Annual Program of cadastral surveys of construction areas for 2022, when aerial photography was done with unmanned aerial vehicles for all areas where a new cadastral survey was carried out. Thus, as part of that work, the geodetic contractor had to submit the following to the State Geodetic Administration: original images, elements of external orientation of shots after equalization, classified point cloud, digital relief model, digital height model, digital orthophoto maps and 3D Mesh (URL 3).

3.2 **3D Land Administration data in Trinidad and Tobago**

There is no 3D national cadastral dataset in Trinidad and Tobago, although, because of significant economic development fueled by high incomes from oil and natural gas exportation, a need for such a dataset has arisen. Many expensive high rise condominiums and apartments would be better served in conveyancing and support of property rights by a 3D cadastre that identifies the extent of the individual interests. The 3D nature of rights is represented on 2D cadastral maps by using cross sections on the maps to identify the different strata and the extents of rights. Figure 6 shows the cross sections on a cadastral plan of a residential building with many levels and many owners. These strata parcels are not included on the 2D cadastral index, are not considered to be separate parcels, and cannot be directly accessed from the online cadastral index.

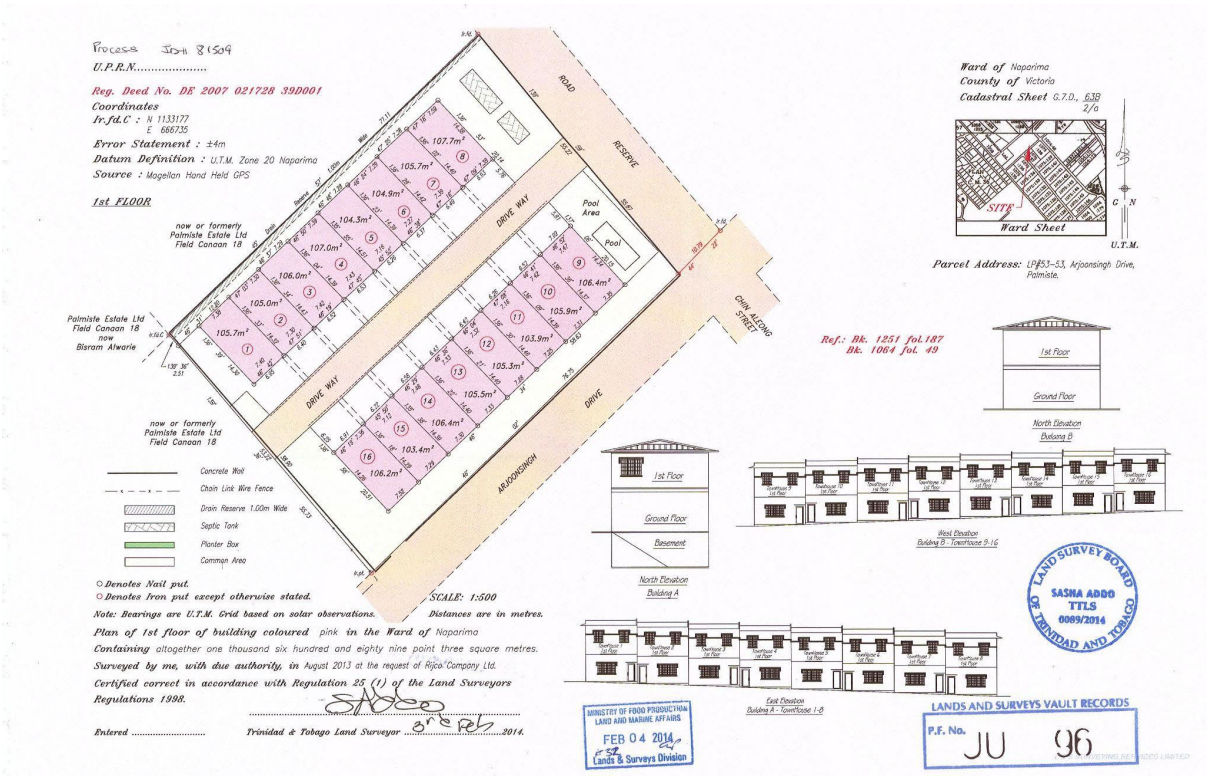


Figure 6. Cadastral maps for townhouses where cross sections indicate the 3D nature

3.3 **LADM in Croatia**

In the Republic of Croatia the implementation of the International Standard ISO 19152 – LADM is more on academic level than in the practice. There are lot of scientific paper regarding LADM and Republic of Croatia mostly produced by Croatian authors. Recent update of Croatin LADM profile produced during 2022 and introduct one new classes *HR_LegalSpaceInfrastructure* in order to support changes occured by adopting the Law on Communal Economy which recognizes different comunal objects that should be registered in cadastre. Introduction of the attribute scale to class *HR_SpatialUnit* follow the changes in geodetic profession (Figure 7). This diagram is mandatory and has a list of possible values defined by *HR_ScaleType*.

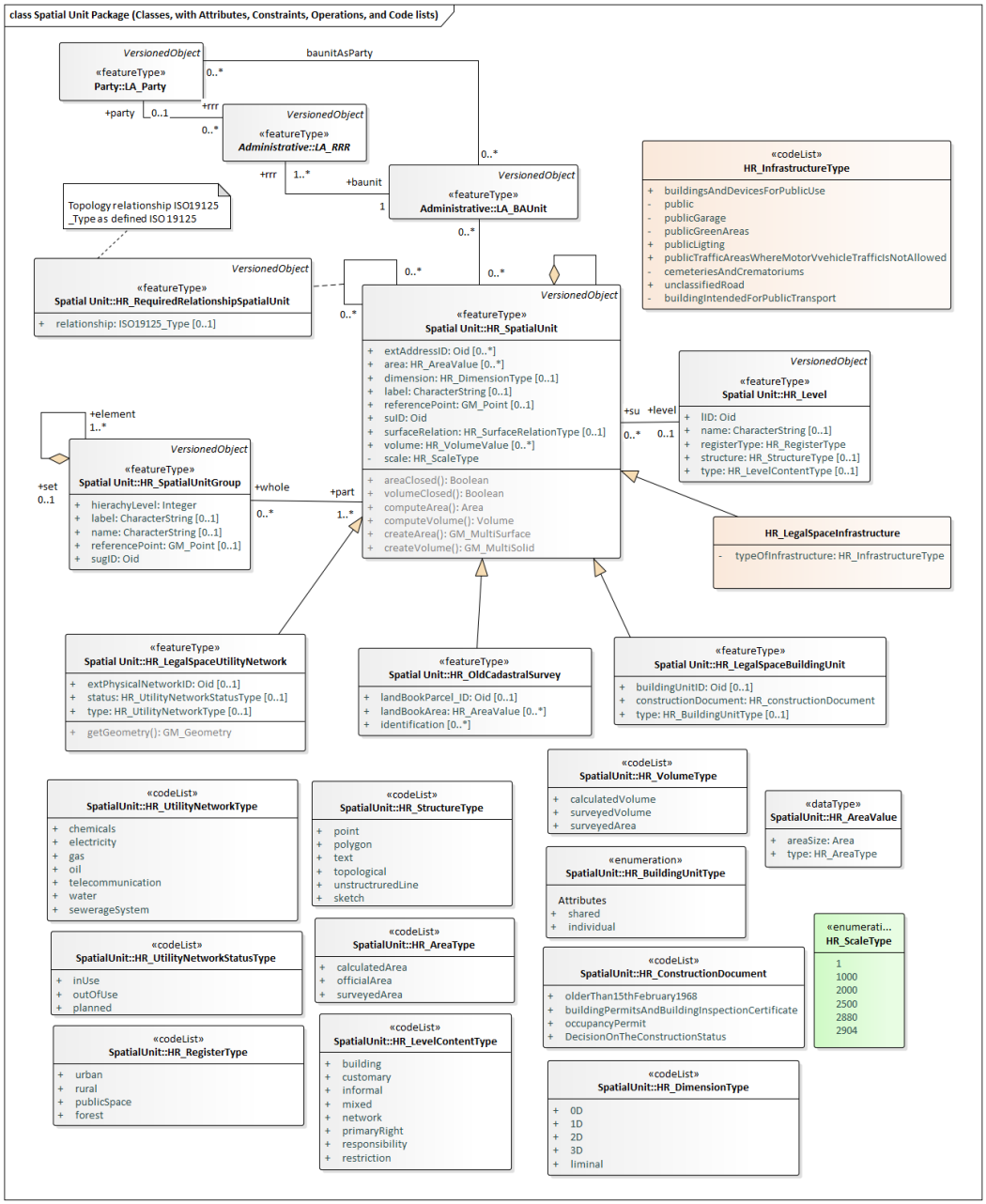


Figure 7. Revised Spatial Unit package of Croatian LADM profile (source Vučić et al. 2022)

3.4 LADM in Trinidad and Tobago

In Trinidad and Tobago the LADM is not being actively deployed and there is no official profile available. Registration of conveyancing on land does not conform to the ISO 19152 as, while the registration document is uniquely identified with an alphanumeric designation, neither the parcel being conveyed on nor the parties to the conveyance are similarly uniquely identified. Conceptual ideas about constructing a LADM profile for the informal parcels in the country have been advanced but not put into practice (Griffith-Charles 2011).

4. DISCUSSION

The importance of a 3D cadastre for Trinidad and Tobago lies primarily in its ability to support conveyancing and an active land market. This segment of the land market is in the upscale and high income residential suburbs of the country. The cost of establishing and maintaining 3D land administration for such purposes may not have the support of the public unless transaction taxes are increased to demonstrate that the state can benefit from this expenditure.

The importance of a 3D Land Administration for Croatia lies primarily in its ability to support the growing economy. The land market in the last few years in the Republic of Croatia was very active. Real estate prices increased rapidly, which coincided with the introduction of the euro as the new national currency. Also the inflation of prices on the European continent in almost every sphere of life has an impact on the real property market. Even though there were big increases in real estate prices, there were enough buyers and investors. Such a situation requires an accurate and precise description of the real property and 3D land administration is the best solution for that. The stakeholders are no longer satisfied with the representation of the building on the cadastral plan in the form of a rectangle, because this representation is completely identical to the one from 205 years ago, when the establishment of the Franciscan cadastre began on Croatian territory.

Cadastral resurvey can be one of the most efficient upgrading from 2D to 3D cadastre in Croatia. In the situation, where cadastral resurvey is selected as the best practice for improving the land administration data, we estimate that with a small extra cost it would be possible to adjust and improve this process so it would also be suitable for the systematic establishment of 3D cadastre in the most efficient way. One way to improve this is to try to use the current ongoing processes for the renewal of land administration data. In the situation, where cadastral resurvey is selected as the best practice for improving the land administration data, the estimation is that with a small extra cost it would be possible to adjust and improve this process so it would also be suitable for the systematic establishment of a 3D cadastre in the most efficient way (Vučić et al 2020).

Table 1 compares similar characteristics of Croatia with Trinidad and Tobago for purposes of comparison of needs, resources and capacities. The needs of both countries are similar as the establishment of a true 3D cadastre would satisfy the land market needs of both countries for condominiums and apartments. However, the differences in the GDPs and the per capita

GDPs indicate that there would be more difficulty for Trinidad and Tobago to channel resources into the project than it would be for Croatia. The needs of Trinidad and Tobago also extend to providing comprehensive land administration for the large percentage of informal occupants of land. This is not a need that Croatia experiences or perhaps experiences at a lower proportion of the population. Good land governance would require that Trinidad and Tobago's limited resources be apportioned equitably to securing the land tenure of all its citizens inclusive of the informal occupants.

Croatia has further advanced in the ability to register apartments and condominiums, even though it is in a separate database than the land parcels. The LADM requires one consistent definition of the land unit or LA_BAUnit. The further advancement points to a larger capacity in its land administration institutions than Trinidad and Tobago where the registration of buildings does not exist although the cadastral parcel maps show the vertical and horizontal sections to illustrate strata rights. While Croatia is ten times the area of Trinidad and Tobago but three times the population, making the task of maintaining currency in its cadastral database more difficult for the Croatians, the capacity of technology can make more effective the programmes of digitisation of the data and digitalisation of the land administration.

Table 1. Comparison of Land Administration systems and 3D products

	CROATIA	TRINIDAD & TOBAGO
Area (mainland)	56594 km²	5128 km²
Area (sea)	31067 km²	7134 km²
Number of inhabitants	3.871.833 (2021)	1,526,000 (2021)
Cadastral system	Title	Deeds and title
Land book principle (if exist)	*Superficies solo cedit*	None
Number of cadastral offices	112	2
Number of Land book offices	109	0
3D products of Land Administration	Joint Information System of Land books and Cadastre Building Cadastre – in the process of establishment Digital Elevation Model Geoportal SGA (3D for earthquake affected towns) oss.uredjenazemlja.hr (link to Google street view)	The cadastre is not 3D and buildings are not registered. No building cadastre Digital Elevation Model Geoportal for 2D cadastre overlaid on imagery None
Condominium registration	Building registration in Land Books	Legislation only in draft
Spatial planning	Closed cooperation with Ministry of Urban Planing and construction and state property Closed cooperation with Local Goverment	No planning cadastre is available
Marine cadastre	Under development	None, but oil and gas exploration block leases are mapped in the marine space
GDP Per Capita	$18,916 US (2021)	$16,000 US (2021)
GDP	$51 billion US (2021)	$24 billion US (2021)

5. CONCLUSION

This paper has explored the digital transformation of land administration systems in two distinct contexts: Croatia, a European Union country, and also Trinidad and Tobago, a Caribbean country. The comparison of these two case studies highlights the importance of aligning digital transformation efforts with a country's unique needs, resources, and capacities.

In Croatia, the focus has been on digitizing cadastral maps and embracing 3D land administration to support a growing economy and an active land market. The implementation of a Building Cadastre and other digital systems has significantly improved services and legal certainty within the land administration system. Croatia's proactive approach demonstrates how digital transformation can be leveraged effectively in a resource-rich environment.

Conversely, Trinidad and Tobago faces challenges in achieving a 3D cadastre due to limited resources and disjointed datasets. While the need for a 3D land administration system is evident, especially in high-income residential areas, the cost and public support remain barriers to its implementation. This case underscores the need for careful consideration of financial and societal factors when pursuing digital transformation initiatives.

This analysis highlights the importance of adapting digital transformation efforts to the specific needs and conditions of each country. Whether a country is resource-rich or resource-constrained, the move toward 3D land administration must be aligned with its economic, legal, and technological realities. In this way, countries can take advantage of digital transformation to support sustainable development, legal certainty and economic growth. Finally, there is no good progress towards 3D land administration without prior digitization and digital transformation of the majority of land administration data.

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BIOGRAPHICAL NOTES

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SDG Land Administration Indicators based on ISO 19152 LADM

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Key words: ISO 19152 LADM, SDGs, Land administration indicators

SUMMARY

The Sustainable Development Goals (SDGs), comprising of 17 Global Goals, serve as a global framework for addressing various facets of sustainable development. Several of these goals emphasize the crucial role of land management and equitable land distribution in achieving sustainable development objectives. ISO 19152, known as the Land Administration Domain Model (LADM), plays a pivotal role in land administration systems globally. It provides a standardized framework for land management, including land tenure, marine georegulation, valuation, and spatial plan information.

This paper explores the integration of land administration indicators within the ISO 19152 standard, aligning them with the United Nations Agenda 2030 SDGs. The process involves a systematic approach to selecting and developing these indicators. In the indicator selection phase, firstly, we establish the foundational lexicon linked to LADM then extract lexemes from SDGs indicators, analyze their semantic relationships, and evaluate their alignment with LADM; secondly, we meticulously evaluated chosen indicators by analyzing their SDG indicator metadata, focusing on the “Method of Computation" section to align these indicators with LADM's basic classes; thirdly, categorizing them based on their association with LADM. This categorization ranges from indicators with no direct correlation to those with full computational interdependence, specifically, they are: Non-Association (Category 0), Full Computational Association (Category 1), Partial Computational Association (Category 2), Indirect Association (Category 3), Association with Other International Standards (Category 4). Following indicator selection, our approach to indicator development is summarized. This entails expressing information from UN SDG "Method of Computation" documents in UML class diagrams, adding operation names and parameters to the most relevant class, and specifying implementation methods for each operation. An in-depth analysis of SDG Indicator 1.4.2 demonstrates the feasibility of deriving indicators entirely from LADM data.

Finally, the paper discusses potential future work, including the integration of semantic networks and ontologies for keyword extraction, further exploration of Category 1 Indicators, and practical implementation through case studies, data collection, indicator testing, validation, and reflection.

SDG Land Administration Indicators based on ISO 19152 LADM

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1. INTRODUCTION

The Sustainable Development Goals (SDGs), a set of 17 Goals, is a global plan of action for people, planet, prosperity, peace, and partnership (United Nations General Assembly, 2015). Among these goals, some are intricately tied to the realm of land, emphasizing the critical importance of effective land management and equitable land distribution for sustainable development. In this context, land administration plays a pivotal role in ensuring the efficient management and just allocation of land resources (UNGGIM, 2020).

ISO 19152, the Land Administration Domain Model (LADM), is a prominent international standard in the field of land administration providing a comprehensive framework that defines conceptual models and standardized methodologies for land administration systems. LADM serves as a crucial tool for nations seeking to enhance their land administration systems, thereby promoting sustainable utilization of land resources and equitable distribution (ISO, 2012). In this paper the new edition of LADM (currently under development) with a wider scope, including land tenure, marine georegulation, valuation, and spatial plan information, is used.

This research endeavor seeks to contribute to the advancement of land administration indicators that align with the United Nations Agenda 2030 SDGs and the ISO 19152 LADM standard. Consequently, the primary aim of this research is to identify the pertinent land administration indicators delineated within the SDGs, with the objective of integrating them within the framework of LADM. This integration is envisioned to provide an effective means to gauge land governance and tenure systems, aligning them with the sustainable development agenda.

Three fundamental hypotheses underpin this ongoing study:

1. By amalgamating the standardized principles and methodologies of ISO 19152 LADM with the overarching goals and targets of the UN Agenda 2030 SDGs, the resulting land administration indicators will manifest as more comprehensive, accurate, and representative.

2. The utilization of these indicators has the potential to bolster evidence-based policy-making, thereby substantively contributing to the realization of SDGs.

3. The effectiveness and expediency of indicator computation can be significantly enhanced through continuous updates to the Land Administration System (LAS).

The rest of this paper is structured as follows: the second section encompasses background information, elucidating the LADM and SDGs; the third section delineates the process of indicator selection, including the method and workflow followed in this paper. Furthermore, the next section gives the indicator development process; the fifth section presents results and examples by selecting a representative indicator and applying the aforementioned processes; and finally, conclusions and proposals for future research are presented.

2. BACKGROUND

In this section the necessary background information and concepts addressed in this paper are introduced. Firstly, the basic concepts of LADM and the developed version, then a quick review of SDGs, which is well known.

2.1 ISO 19152:2012 LADM basic concepts and ongoing revision

ISO 19152 LADM, the Land Administration Domain Model, is an international standard and a conceptual framework (ISO, 2012). It serves the purpose of describing land administration systems, focusing on aspects related to land rights, responsibilities, restrictions, and their geospatial components. The primary goal of this standard is to facilitate communication among various parties, both domestically and internationally, by providing a shared vocabulary (ontology) and a formal language (Unified Modeling Language, UML) to describe people-to-land relationships. It does not intend to replace existing systems but rather serves as a descriptive tool for these systems, enhancing the comprehension of their similarities and difference. While LADM is a generic model, it can be extended and customized for specific regions or countries, making it a versatile tool in the field of land administration.

Widely adopted by international organizations(UNGGIM, 2018) like the United Nations and the World Bank, LADM serves as a common language for different stakeholders such as land surveyors(Aditya et al., 2021), land registrars(Beck et al., 2021) and land managers(Lisjak et al., 2021) and therefore, the first edition of the standard has been widely known around the world, with various country profiles being developed as reported by(Kalogianni et al., 2021). Currently, around ten countries around the world have implemented LADM as a part of their land administration systems, including Scotland, Indonesia and Colombia, while more than 15 countries have adopted the Social Tenure Domain Model (STDM), a specialized solution based on LADM, including Democratic Republic of the Congo, Kenya and Lao PDR(Njogu et al., 2023).

The scope of LADM Edition I is limited to the land tenure component of the LA paradigm (see the grey circle in Figure 1), whereas LADM Edition II aims to extend the scope of Edition I to include land value, land use and land development (red circle in Figure 2) (Kara et al., 2023).

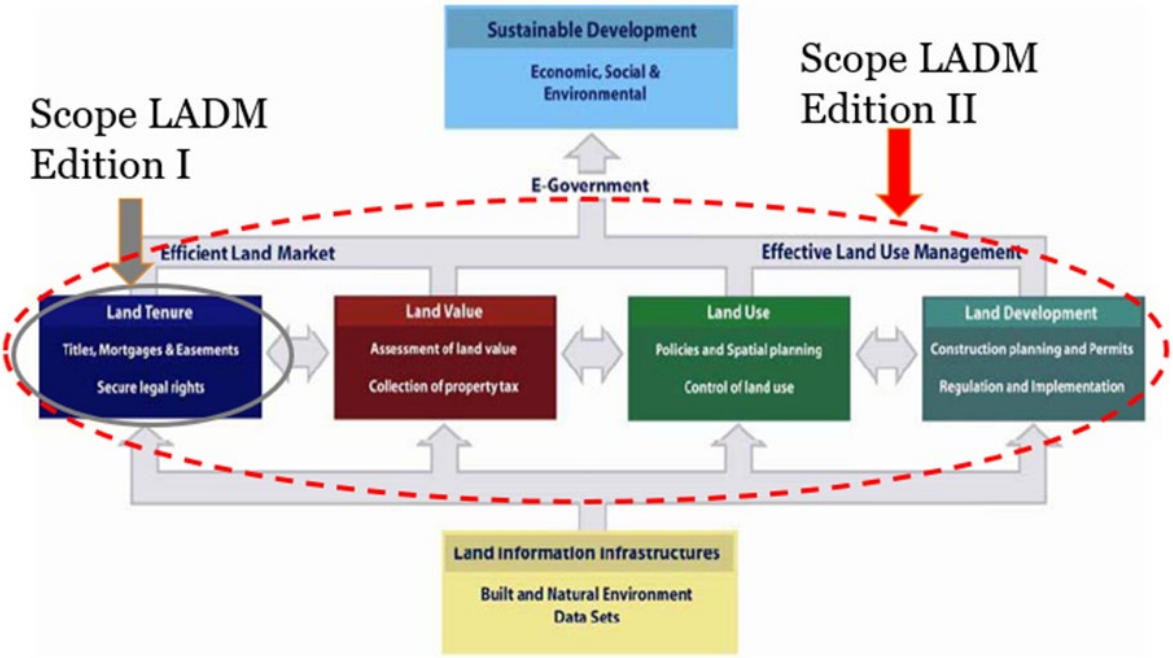


Figure 1. Land Administration paradigm and LADM scope (Kara et al., 2023; adapted from Enemark, 2006**)**

Currently, the second edition of LADM is under development, comprising of six parts (Figure 2), which build upon the solid foundation laid by the initial standard. This expanded edition encompasses a range of crucial domains, including Marine Georegulation, Valuation Information, and Spatial Plan Information. Kara et al. (2023)provide a detailed overview of the latest developments of the second edition of the standard.

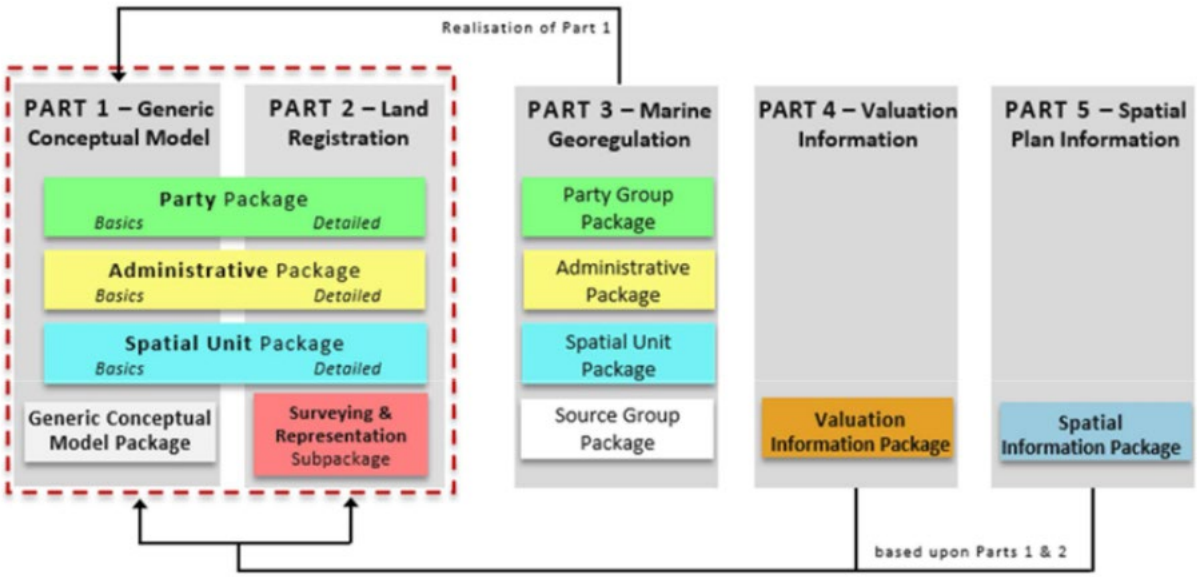


Figure 2. LADM Edition II Parts 1-5 (Kalogianni et al., 2023)

2.2 SDGs and Land

The SDGs are broad in scope, comprising 17 overarching goals, 169 targets and 248 different indicators (of which 231 are unique), some of which are further subdivided into sub-indicators (e.g., indicators 1.4.2, 5.a.1, 11.5.3, etc.). The SDGs aim to address a range of social, economic and environmental challenges facing the world. Land underpins the SDGs as it covers many of the goals, particularly those related to the environment, food security, economic development, urbanisation and climate change.

3. INDICATOR CLASSIFICATION AND SELECTION

A systematic methodology is developed for the purpose of refining and discerning indicators from SDGs of relevance to the objective of this paper and is in line with the LADM, as presented in Figure 3. The Steps are explained at the following paragraphs.

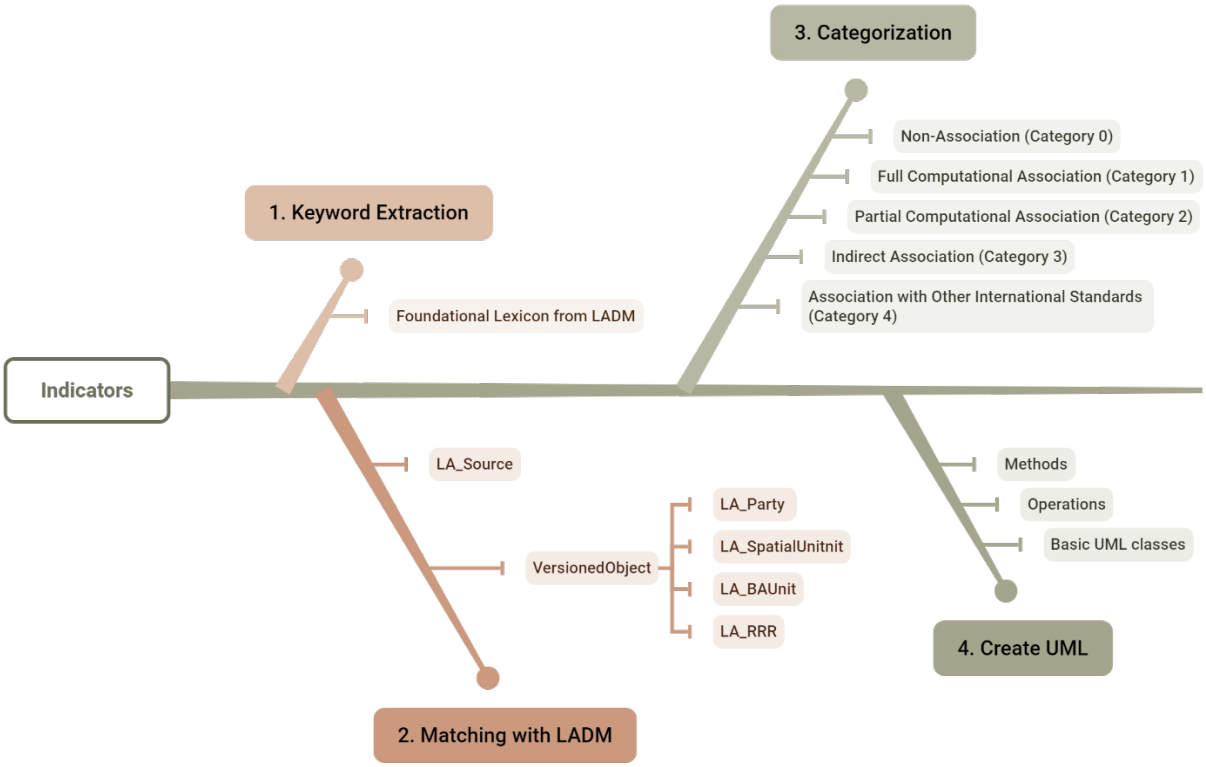


Figure 3. General Flow

3.1 Step 1: Keyword Extraction and Preliminary Filtering:

First and foremost, it becomes indispensable to use the core terminology of the LADM to create a first filtering for the identification of the relevant indicators. The core terms constituents: Land, Party, RRR (Rights, Responsibilities, Restrictions), Spatial Units, Marine, Valuation and Spatial Plan.

At the documents of the various parts of the LADM Edition II that are being submitted in the different stages of the standardization process, the definition of these terms is provided. Specifically:

1. **Land**: spatial extent that is defined by RRRs and encompass the surface of the earth, strata, sub-strata or the marine environment, like a building;
2. **Party**: person or organization that plays a role in a rights, responsibilities or restrictions transaction, like natural person;
3. **Rights**: formal or informal entitlement to own or do something;
4. **Responsibilities**: formal or informal obligation on the land owner to allow or do something;
5. **Restrictions**: formal or informal obligation on the land owner to refrain from doing something;
6. **Spatial Units**: the areas of land (or water – e.g., water rights and the marine environment) where the rights and social tenure relationships apply;
7. **Marine**: relating to navigation or shipping; relating to or connected with the sea; used, or adopted for use at sea;
8. Valuation: process of estimating value of an immovable property;
    a. **value**: value of a property or a property unit estimated under certain assumptions at a particular moment of time;
9. **Spatial Plan**: a set of documents that indicates a strategic direction for the development of a given geographic area, states the policies, priorities, programs and land allocations that will implement the strategic direction and influences the distribution of people and activities in spaces of various scales;
    a. **plan** unit: homogenous smallest area/space (2D/3D) with assigned function/purpose to represent the potential land use development according to the spatial planning authorities at the highest detail, largest scale (usually the municipality/ neighborhood level)
10. Source: document providing legal and/or administrative facts on which the LA object (right, restriction, responsibility, basic administrative unit, party, or spatial unit) is based on.

Subsequently, relevant terminology from the SDGs indicators is extracted. Meanwhile, the complex semantic interplay among these extracted terms, decodes the relationships that may encompass synonymy, hypernymy, or contextual relevance. Each term is subjected to careful evaluation, gauging its alignment with the core LADM terminology, thereby facilitating the creation of a semantic bridge between the landscape of SDGs and the land administration domain. This reveals the consistency and nuances of expression between the terminology of the SDGs and LADA, thus laying the foundation for harmonization between the two areas.

3.2 Step 2: Matching with LADM core classes

The selected indicators underwent a rigorous evaluation process, which involved a comprehensive analysis of their corresponding SDG indicator metadata documents(United Nations, 2023) and a rigorous matching process.

A key aspect of this evaluation was the meticulous examination of specific sections within the indicator metadata documents(United Nations, 2023), namely, “0.f. Related indicators”, “2.a. Definition and concepts”, “3.a. Data sources” and “4.c. Method of Computation”. Briefly:

1. **For “0.f. Related indicators”**, it identified related indicators to understand their connections and potential overlaps, aiding in defining the evaluation scope, like for Indicator 5.1.1 “*Whether or not legal frameworks are in place to promote, enforce and*

monitor equality and non-discrimination on the basis of sex", to avoid duplication, it does not cover areas of law that are addressed under indicator 5.a.2 *"Proportion of countries where the legal framework (including customary law"* guarantees women's equal rights to land ownership and/or control);

2. **For "2.a. Definition and concepts",** it provides explanations for the more generalized text used in the indicators. For example, for indicator 1.4.1, "*Proportion of population living in households with access to basic services*", the precise definition of "basic services" is elaborated upon;
3. **For "3.a. Data sources"**, it gives information on the potential databases and the organizations responsible for data collection, allowing for a quick assessment of whether they are relevant to the data involved in LADM;
4. **For "4.c. Method of Computation"**, the specific calculation methods for each indicator are detailed, which encompasses a variety of approaches, like the formulation of mathematical equations, tabulated scoring systems, etc. This section also plays a pivotal role in the subsequent classification of indicators.

This thorough analysis was instrumental in ensuring the accuracy and reliability of the chosen indicators, as it provided a deep understanding of the conceptual framework and technical aspects underpinning them.

Subsequently, a rigorous alignment process was conducted, associating the basic classes (and sub-classes) from the various parts of LADM Edition II with these selected indicators. As previously mentioned, the basic classes are LA_Party, LA_SpatialUnit, LA_BAUnit, LA_RRR, VM_ValuationUnit and SP_PlanUnit and they are all inheriting from VersionedObject (and associated to LA_Source). For those indicators that could be matched and have clear calculation formulas, the data names that LADM couldn't provide and might require sourcing from external datasets should be noted.

3.3 Step 3: Indicator Categorization:

In this pivotal third step, a comprehensive classification of the selected indicators was executed, grounded in their nuanced relationships with the Land Administration Domain Model (LADM). The categorization criteria employed are elucidated as follows:

1. **Non-Association (Category 0)**: These indicators demonstrate no discernible direct or computational correlation with LADM.
2. **Full Computational Association (Category 1)**: Indicators falling within this category exhibit an unequivocal and comprehensive computational interdependence with LADM. All the data required for the calculation of these indicators can be obtained from a Land Administration System that conforms to the LADM.
3. **Partial Computational Association (Category 2)**: These indicators, while partly reliant on data provided by LADM for their calculations, necessitate additional external data sources. They thus establish a partial computational nexus with LADM.
4. **Indirect Association (Category 3)**: LADM offers supportive roles during the indicator generation process.
    a. Indicator involves LADM elements (classes or attributes) but lacks direct expression (and therefore calculation) within the structure of the model. For example, for the indicator "*14.6.1 Degree of implementation of international*

instruments aiming to combat illegal, unreported and unregulated fishing", the computation method is based on surveys and scoring, and it is related to elements such as marine and land rights within LADM.

b. Indicator indirectly utilizes LADM elements, and their final expressions do not have directly relation with LADM. For instance, the indicator "*1.2.2 Proportion of men, women and children of all ages living in poverty in all its dimensions according to national definitions*", "Poverty" includes a "housing" dimension, which is related to "BAUnit".

5. **Association with other Standards (Category 4):** Indicators categorized as such are fundamentally linked with other (international) standards in order to be computed and potentially may partly rely on the LADM.

3.4 Step 4: Create UML

This last step focuses on describing the computational process of the indicator within the UML diagram. Specific processes and examples are presented in the Chapters 4 and 5.

4. INDICATOR DEVELOPMENT

Following the categorization into the distinct classes, the next crucial step is the actual development of the indicators. This process involves translating the indicator's computational requirements and dependencies into practical and systematic implementations. The following approach is used to document the indicator development:

1. **Representation with UML**: To begin, the information stipulated in the "4.c. Method of Computation" was meticulously expressed using UML (Unified Modeling Language) class diagrams. Here there can be various cases:
   a. information is based on in LADM,
   b. information is based on in other standards (e.g., ISO 19144 (ISO, 2012)),
   c. information is not known based on a standard, but can be extracted from other databases (this is modelled via blueprint/external classes diagram to be developed to capture description of this information in the UML)
2. **Add compartment**: For the most relevant class, a dedicated compartment is used in the computation of the indicator values. This compartment contains the name and parameters of the added operations. Please note that the spatial extent (whole country, province, municipality) and temporal extent (decade, year, month) may vary. A typical operation could be to compute an indicator value in a specific year and for a specific area; e.g., compute indicator X (year, area).
3. **Implementation Method**: For each operation, a well-defined implementation method is specified within the UML diagram. This includes an attached note defining the steps of computation. The implementation methods are articulated using programming languages (i.e., Python, Java, pseudo code). Crucially, these methods were aligned with the information elements delineated in the utilized UML classes.

This systematic approach ensures a structured and comprehensive documentation of indicator development, facilitating clarity and transparency in the computational processes associated with each indicator

5. USE CASE INDICATOR DEVELOPMENT

For the comprehensive understanding of the indicator selection and development, the SDG Indicator 1.4.2 "Proportion of total adult population with secure tenure rights to land, (a) with legally recognized documentation, and (b) who perceive their rights to land as secure, by sex and type of tenure" is selected for in-depth analysis. Firstly, the classification into the categories mentioned in the previous sections is carried out and as a second step the computational method of the indication development is presented and visualized in UML.

5.1 Indicator classification

Step 1: Keyword Extraction:

Firstly, in order to make an initial judgement on whether the SDG 1.4.2 indicator is related to LADM, the indicator description needs to be analyzed. The process of "Identification of Noun Phrases - Filtering Redundant Vocabulary -" was used, as shown in Figure 4.

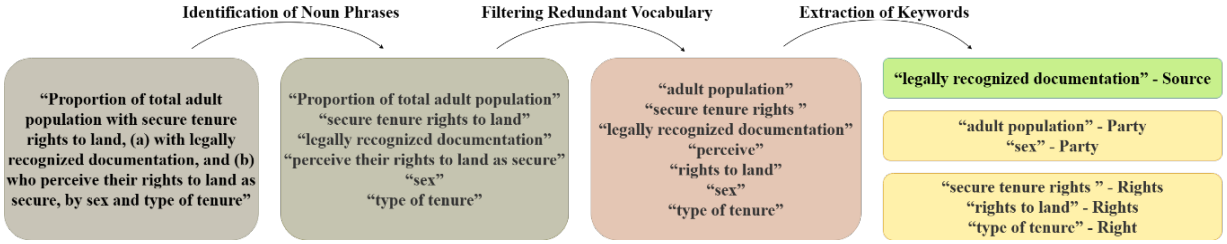


Figure 4. Keywords Extraction for SDG 1.4.2

According to the Figure 4, the keywords include "legally recognized documentation", "adult population", "sex", "secure tenure rights", "rights to land" and "type of tenure", and their corresponding LADM core terms are "Source", "Party" and "Rights". Therefore, we can now tentatively SDG 1.4.2 indicator is somewhat related to LADM.

Step 2: Matching:

In the SDG Indicator1.4.2 metadata document(United Nations, 2023), according to the "2.a. Definition and concepts" section, we can find that the indicator are divided into 2 parts:

- Part (A) quantifies the proportion of adults possessing legally recognized documentation over land within the total adult population.
- Part (B) emphasizes the proportion of adults who perceive their land rights as secure within the adult population.

Mathematically, these parts are represented as follows:

$$\text{Part (A): } \frac{People\ (adult)\ with\ legally\ recognized\ documentation\ over\ land}{Total\ adult\ population} \times 100$$

$$\text{Part (B): } \frac{People\ (adult)\ who\ perceive\ their\ rights\ as\ secure}{Total\ adult\ population} \times 100$$

Therefore, to meet the metadata documentation requirements, it is necessary to collect three types of data: (a) the number of adults possessing legally recognized documentation over land (for Part A), can be derived from a cadastre system compliant with LADM; (b) the number of adults who perceive their land rights as secure (for Part B), can only be obtained through household survey (or relevant historical data stored in external databases); and (c) the total adult population (for both), made available from censuses or inter-censual projections.
Therefore, based on the analysis carried out, the following conclusions were drawn:

- "Secure tenure rights" and "Type of tenure" are related to LA_RRR (Rights, Responsibilities, Restrictions) class due to its connection to the nature of land rights.
- "Legally recognized documentation", as mentioned in the metadata file, is legal documentation of rights refers to the recording and publication of information on the nature and location of land, rights and right holders recognized by government. So, it is related to LA_Source.
- "Sex" could be an attribute of LA_Party.

Step 3: Classifying:
Finally, the SDG 1.4.2 indicator was categorized based on its relationship with LADM. The specific categorization is as follows:

- SDG Indicator 1.4.2 (a) is classified under the "Partial Computational Association (Category 2)". SDG Indicator 1.4.2 (b) is categorized under the "Indirect Association (Category 3)". So, SDG Indicator 1.4.2 is classified under the "Partial Computational Association (Category 2)".

5.2 Indicator development

Based on the steps of indicator development mentioned in earlier sections, the computation of SDG Indicator 1.4.2 is shown via UML diagram. In Figure 5, distinct colors are employed to enhance readability; with yellow representing classes belonging to VersionedObject, green denoting LA_Source, red signifying external classes, and blue indicating methods that implement operations.

The specific steps in the modeling process are as follows:

1. **UML Diagram Representation**: To begin, the core components of the LADM, including LA_Party, LA_RRR, LA_BAUnit, and LA_Source into the UML diagram describing the indicator computation are introduced.To fulfill the requirements of SDG Indicator 1.4.2, an external class named "SecureLandRightAdult" is introduced to represent the molecular aspect of Part B and an external class named "Population".

2. **Addition of Attributes and Operations**: Within the LA_Party class, emphasis is given on key attributes:
    a. "birth day" is employed for subsequent identification of adults in relevant calculations.
    b. "gender" serves the purpose of categorizing adults.

   Additionally, we introduced vital operations:
    c. "countAdult" facilitates the determination of the total count of adults.
    d. "hasLegalLandCertification" is crucial for verifying whether this party possesses legal documents related to land.

   Furthermore, focus was given on the LA_Right class and specifically the attribute "LA_RightType" that categorizes the various types of land tenure, aligning with the "type of tenure" parameter in the indicator.

   An external class, the SecureLandRightAdult is introduced and features information further aiding in adult identification, while operations designed to assess the perception of land rights are introduced, including:
    a. "Perception" which signifies the degree of land rights security. It utilizes the LandRightPerception codelist encompassing values like +0 - insecure and +1 - secure.
    b. "PerceiveRightAsSecure()" an operation that determines whether land rights are perceived as secure, yielding a Boolean outcome.

3. **Implementation Method**: To carry out the "+ countAdult" operation effectively, the following pseudocode has been developed. It outlines the steps for counting adults based on their birth dates. It initializes a counter, retrieves the current date, and then iterates through each individual's birthdate. Using the "calculateAge" function, it determines their age and increments the count if the age is over 18. Finally, the operation returns the total count of adults.

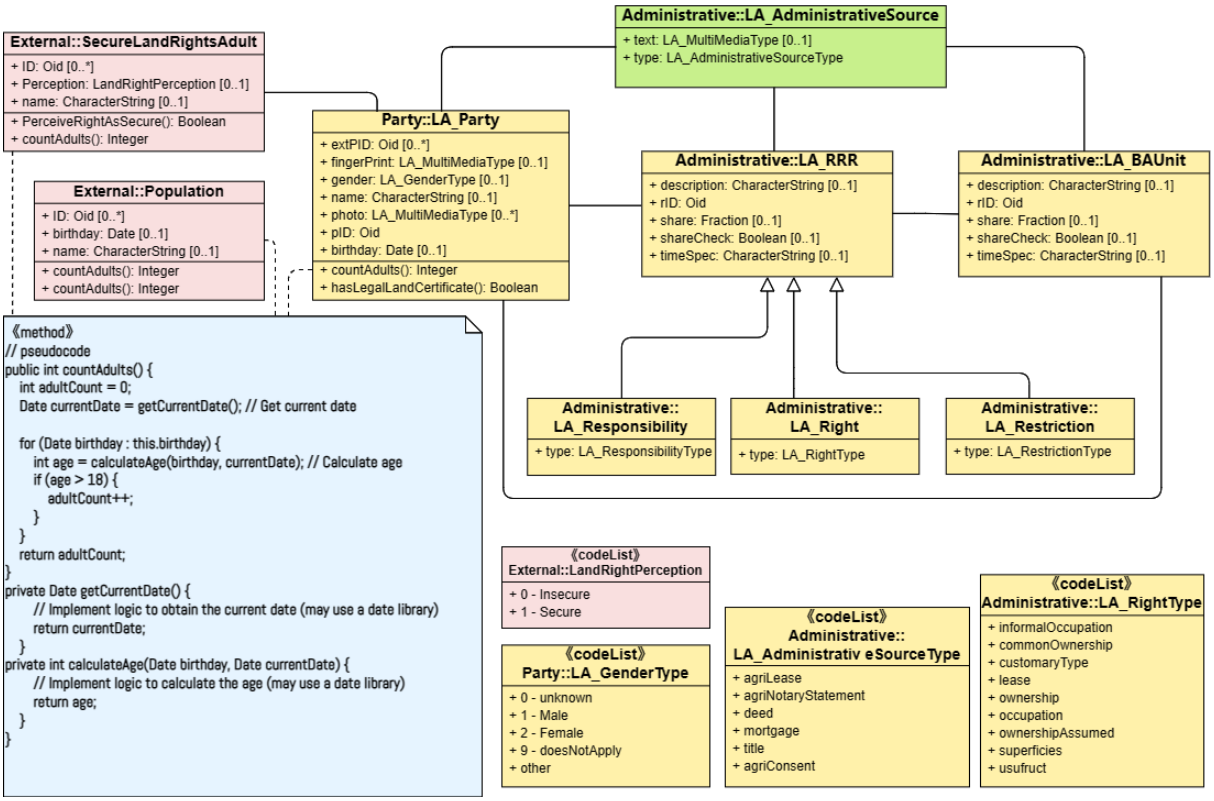


Figure 5. Modelling of SDG Indicator 1.4.2 calculation in UML class diagram

6. CONCLUSIONS AND FUTURE WORK

In the context of this paper, an investigation of the relevance between SDGs and LADM is carried out, aiming to provide initial results of how (and if) relevant indicators can be computed (directly or indirectly) through LADM. Therefore, a comprehensive classification and analysis of a range of SDGs is conducted to assess their degree of association with the LADM, leading to the following key categories:

1. Category 0 Indicators: In total, 220 indicators are identified falling into this category, indicating no direct association with LADM. These indicators do not require any data or information related to LADM in their computation processes.
2. Category 2 Indicators: A total of 10 indicators were identified in this category, which. partially rely on data provided by LADM for their calculations but may also require additional external data. These indicators span various domains, including land use, water resources management, road connectivity, and more.
3. Category 3 Indicators: There are 11 indicators in this category, that lack explicit computational formulas, LADM has an indirect impact on the results of these indicators. This implies that LADM plays a supportive role in the indicator generation process, particularly in land use planning and forest management.
4. Category 4 Indicators: In total, 6 indicators are identified in this category that are closely related to other (international) standards and may require the concurrent use of LADM to meet international compliance requirements for their computation. They

cover various domains, such as land ownership, water resources management, and land use planning.

The selected indicators cover a wide range of areas, including poverty, basic services, land rights, economic losses, agriculture, drinking water, water management, transport, housing, land use, watershed management, forests and protected areas. However, for different category, they have different focus. Category 2 underscores the significance of secure land tenure rights, scrutinizing both legally recognized documentation and the perception of land rights as secure, with a distinct focus on gender equality. In Category 3 indicators probe into the dimensions of poverty concerning housing, accessibility to potable water, and the legal frameworks governing land and water rights, including aspects of gender equality. Furthermore, Category 4 delves into the domain of Environmental Preservation, encapsulating the coverage of protected areas, forestland, and the impact of land degradation. It appears that for Category 1, there are currently no indicators that can solely rely on LAS in line with LADM. However, this observation also highlights the strong relationship between land administration and various sustainability goals and indicators. While direct indicators within Category 1 may not be present, it is evident that land administration and specifically, LADM play a vital role in supporting and contributing to the achievement of broader sustainability goals across different categories and indicators.

This paper presents a preliminary analysis and results regarding LADM and SDG, providing solid ground for future work. Important topics for further exploration are:

1. **Semantic Network and Ontology Integration:** The initial step of indicator selection, which involves Keyword Extraction and Preliminary Filtering, as presented relies on manual literature review. A promising avenue for future research lies in the adoption of advanced semantic network techniques and ontology construction methods. Leveraging these technologies could streamline the process by automating keyword extraction and enhancing the precision of indicator selection. This approach would not only expedite the process but also reduce the potential for bias in keyword selection.
2. **Further Exploration of Category 1 Indicators:** At present, no Category 1 Indicators (those that can be entirely derived from LADM data) . In light of the aforementioned recommendation, next step would be to revisite this category by employing advanced techniques to explore the possibility of identifying indicators that can be exclusively derived from the Land Administration System and LADM-compliant data sources.
3. **Practical Implementation and Case Studies:** Current work of this paper has predominantly focused on theoretical aspects and future work includes encompassing practical implementation. This includes:
    a. **Case Study:** Undertaking a comprehensive case study within a specific country or region to assess the developed indicators in a real-world context. This endeavor would aim to evaluate land governance and tenure using (3D) Land Administration Systems (LAS) based on LADM. The study would address fundamental questions such as "*How can LAS be assessed using these indicators?"* and "*How can the assessment outcomes be effectively visualized?*"
    b. **Data Collection:** Detailing the process of collecting relevant data for the case study, encompassing a wide array of sources such as land administration records, survey data, remote sensing data, or any pertinent information

necessary for computing the selected indicators, ensuring transparency and reproducibility.

c. **Indicator Testing and Validation:** Conducting rigorous testing and validation of the selected indicators using the collected data. This phase would involve the calculation and analysis of the indicators, followed by a comparative analysis with existing methods or indicators. Key questions to address would include "*How do the results of the newly computed indicators compare with existing methods?*" and "*What are the relationships between the values of newly computed indicators and those reported by current methods?*" This phase would also assess the validity and reliability of the newly computed indicator values.

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BIOGRAPHICAL NOTES

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LADM's Links with International Standards, Guidelines and Frameworks

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Key words: LADM, ISO/TC 211, IPMS, ILMS, SDG, FELA, VGGT, FFPLA

SUMMARY

The first edition of the Land Administration Domain Model (LADM) has been available as a formal International Standard since the 1st of December 2012, published as ISO 19152:2012. It is based on / makes use of a number of standards, in particular those published by ISO/TC 211 and, of course, other committees. In addition, non-ISO standards and international guidelines related to land administration have been used as much as possible in the development of LADM Edition I.

The systematic review of LADM Edition I has been officially launched and the process of developing LADM Edition II is now underway. The new edition not only refines the content of LADM Edition I, but also expands the scope to include marine georegulation, valuation information, spatial plan information and implementation. As a result, LADM Edition II is based on more standards, not only because of its expanded scope, but also because of the standards published after LADM Edition I and the principle of reusing existing standards wherever possible.

Since the publication of LADM Edition I, it has been widely recognised by the international community and implemented by several countries. It is also applicable to the implementation of relevant parts of international standards, guidelines and frameworks, as well as the Sustainable Development Goals (SDGs). LADM Edition II has somewhat more links to international standards, guidelines and frameworks, as its scope is broader than Edition I.

The purpose of this paper is to document which standards LADM Edition II is based on and associated with, which guidelines and frameworks are in some way related to LADM.

LADM's Links with International Standards, Guidelines and Frameworks

Abdullah KARA, Eva-Maria UNGER, Peter VAN OOSTEROM and Christiaan LEMMEN, The Netherlands

1. INTRODUCTION

The Technical Committee 211 (TC 211) of the International Organisation for Standardisation (ISO) publishes standards for data management in the field of digital geographic information related to objects or phenomena that are directly or indirectly associated with a location relative to the Earth (ISO/TC 211, 2023). One of the standards of ISO/TC 211 is the Land Administration Domain Model (LADM), which has been available as a formal International Standard since the 1st of December 2012, published as ISO 19152:2012. LADM Edition I focuses on the part of land administration that is interested in rights, responsibilities and restrictions affecting land, and the geometrical (geospatial) components thereof (ISO, 2012). LADM Edition I is based on a number of standards, in particular those published by ISO/TC 211 and, of course, other committees, as well as standards published by other international bodies and guidance documents published by land administration communities.

Five years after the publication of LADM Edition I, discussions for a systematic revision were initiated during the UN-GGIM Expert Group Meeting on Land Administration and Management in Delft, the Netherlands, in March 2017, and it was concluded that a revision of LADM Edition I is needed to provide better tools for tenure security and better coverage of land administration, see UN-GGIM (2020). The systematic review includes not only refining the content of LADM Edition I, but also expanding the scope to include marine georegulation, valuation information, spatial plan information and implementation (Lemmen et al., 2019). As a result, LADM Edition II is based on more standards, not only because of its expanded scope and the refinement of existing scope, but also because of the standards published after LADM Edition I and the principle of reusing existing standards wherever possible. There is a long list of standards here also for Part 3, 4 and 5 of LADM Edition II. Part 3 is based on the existing International Hydrographic Organization (IHO) standards, namely IHO S-100 the Universal Hydrographic Model and IHO S-121 Maritime Limits and Boundaries (IHO, 2018, 2019; Beaupré, 2022). Part 4 adopted several terms and definitions from technical standards of the International Association of Assessing Officers, OGC's LandInfra and the International Property Measurement Standards (IPMS): All Buildings (IPMSC, 2023) while Part 5 benefits from the conceptual framework of Plan4all (Čerba, 2010).

Since its publication, the LADM and its specialization, the Social Tenure Domain Model (STDM), have been widely recognised and implemented by several countries. Moreover, LADM and STDM are also applicable in relation to the implementation of relevant parts of international guidance documents such as the New Urban Agenda (UN, 2016), the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security (FAO, 2012), UN-HABITAT's Secure Land Rights for All (UN-HABITAT, 2008), the UN-GGIM Expert Group on Land Administration and Management's Framework for Effective Land Administration A reference for developing,

reforming, renewing, strengthening, modernizing, and monitoring land administration (UN-GGIM, 2019) and Fit-for-Purpose Land Administration: Guiding principles for country implementation (UNHabitat/GLTN/Kadaster, 2016). This, of course, fits very well into the context of the implementation of the Sustainable Development Goals (SDGs).

This paper aims to document which standards LADM Edition II is based on and associated with, and which guidelines and frameworks are related to LADM in some way (e.g., LADM based on this guideline, this guideline refers to LADM, or LADM can be used to implement this guideline). The remainder of the paper is organized as follows: Section 2 explores the relationships between the parts of LADM Edition II and other international standards. Section 3 examines which and how the international guidelines and frameworks relate to LADM Edition II. Section 4 concludes the paper.

2. LADM AND OTHER INTERNATIONAL STANDARDS

The development of LADM Edition I is based as much as possible on the standards published by ISO/TC 211. In fact, this approach is actually followed by all ISO standards including ISO/TC 211 as well as the standards published by other standard setting bodies such as Open Geospatial Consortium (OGC). This approach avoids the production of repetitive standards in terms of terms, concepts, definitions and models; enables the development of interoperable standards and paves the way for sustainable standardization. This approach has also been followed in the development of LADM Edition II.

ISO documents, including ISO/TC 211 standards, are all subject to systematic review. For an international standard, this period is five years (ISO, 2023a). Between the publication of LADM Edition I and the start of development of LADM Edition II, a number of standards have been reviewed/updated. As a result, the standards on which LADM is based may differ between the editions. The standards on which LADM Edition I is based are listed in the normative references section. The approach to referencing normative references in ISO standards changed after LADM Edition I was published. All ISO standards must be based on a set of requirements. According to this new approach, a normative reference covers only those standards that are cited in at least one requirement. If a standard refers to another standard in the main text but not in a requirement, that standard should be cited in the references section. Therefore, the number of normative references in LADM Edition II Part 1 and Part 2 is less than in LADM Edition I. However, LADM Edition II Part 1 and Part 2 refer to more standards than in Edition I. It should be noted that the content of LADM Edition I is covered in Part 1 and Part 2 of LADM Edition II with refinements and extensions.

2.1 LADM Edition II Part 1

The standards, to which both the LADM Edition I and the LADM Edition II Part 1 and Part 2 used as a normative reference are: ISO 19103, ISO 19105, ISO 19107 and ISO 19109. As all the other parts of LADM Edition II (namely Part 2, 3, 4, and 5) are based on Part 1, the normative references in Part 1 are also normative for the other parts mentioned. In particular, Part 3 is based on Part 1, while Part 4 and Part 5 are based on both Part 1 and Part 2.

The terms and definitions used in the development of LADM Edition II Part 1 are listed in Table 1.

Table 1. Terms used from other standards and guidance document in LADM Edition II Part 1

Standard	Term	Definition of the term
ISO 19101-1:2014	Feature	Abstraction of real-world phenomena
ISO 19105:2022	Abstract test suite	Set of conformance classes that define tests for all requirements of a specification
ISO 19106:2004	Profile	Set of one or more base standards or subsets of base standards, and, where applicable, the identification of chosen clauses, classes, options and parameters of those base standards, that are necessary for accomplishing a particular function
ISO/CD 19135:2023	Register	Managed collection of information
ISO/CD 19135:2023	Register system (Registry)	Information system on which a register is maintained
ISO 19156:2023	Feature type	Class of features having common characteristics
ISO/IEC 8824-1:2021 (adapted from)	Object identifier (Oid)	Generic object identifier providing support in object identification
ISO/IEC Guide 2:2004	Regulation	Document providing binding legislative rules, that is adopted by an authority
UNECE Land Administration Guidelines with special reference to countries in transition (Adapted)	Land administration	Process of determining, recording and disseminating information about the relationship between people and land

The standards and their relevant parts used in the development of the Part 1 data model are listed in Table 2. The standards in bold are the normative references in Part 1.

Table 2. Standards used in the LADM Edition II Part 1 data model and their relevant parts

Standard	Class
ISO 19103:2015 Geographic information — Conceptual schema language	DateTime, CharacterString, Integer
ISO 19105:2022 Geographic information — Conformance and testing	- (Abstract test suite)
ISO 19106:2004 Geographic information — Profiles	- (Abstract test suite)
ISO 19107:2019 Geographic information — Spatial schema	- (Geometric elements)
ISO 19109:2015 Geographic information — Rules for application schema	- (General future model)
ISO 19115-1:2014 Geographic information — Metadata — Part 1: Fundamentals	CI_Responsibility, CI_PresentationFormCode
ISO 19157-1:2023 Geographic information — Data quality — Part 1: General requirements	QualityElement

One of the most used standards in data model of the LADM is *ISO 19103 Geographic Information — Conceptual schema language*. While the 2005 version (ISO/TS 19103:2005) is used in LADM Edition I, the 2015 version is utilized in LADM Edition II (ISO 19103:2015). This standard "*provides rules and guidelines for the use of a conceptual schema language within the context of geographic information*" (ISO, 2015a). ISO 19103 includes interface

classes that define textual information (i.e., CharacterString), timestamp information (i.e., DateTime), logical information (i.e., Boolean), numbers (i.e., Decimal, Integer, Real), truth (i.e., Boolean) and measure (i.e., Area, Volume, Distance, Angle, Currency), see Figure 1. It should be noted that only CharacterString and DateTime classes are utilized in Part 1 (how this standard is used in the other relevant parts is shown in Tables 4, 6, 8 and 10). ISO 19103 is currently under systematic review. If there are any changes to this standard that apply to LADM, these will be taken into account in the development of LADM Edition II.

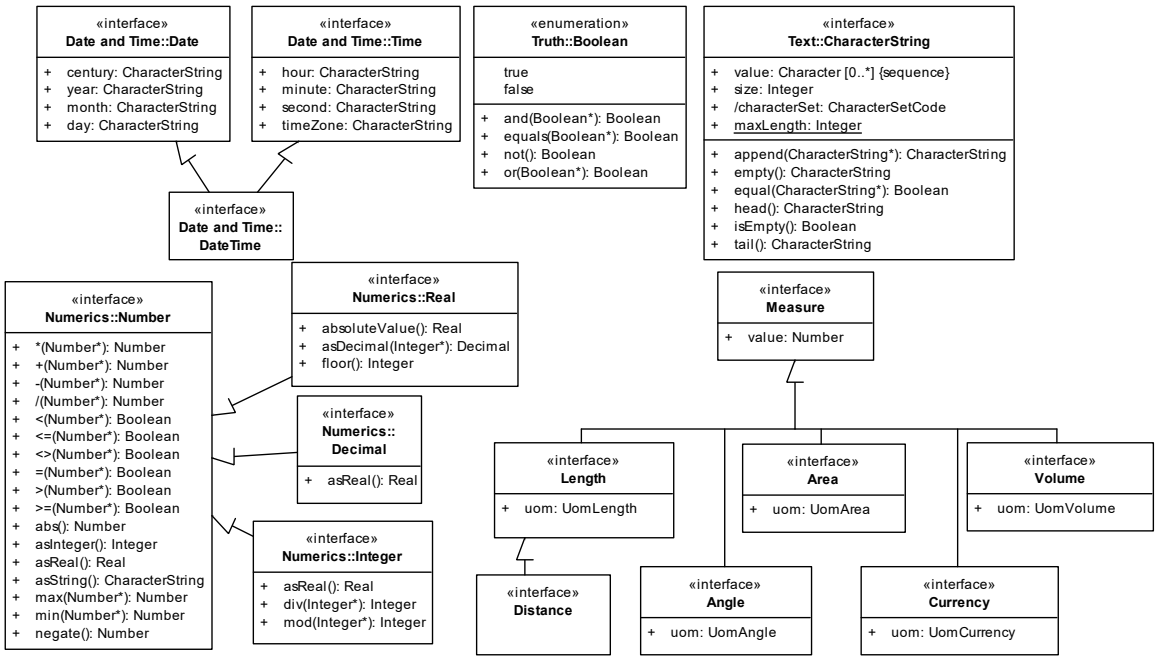


Figure 1. The ISO 19103 classes used in the development of LADM (ISO, 2015)

ISO 19105 Geographic information — Conformance and testing is another standard that LADM utilized for testing conformance to LADM. This standard "*provides a framework for specifying abstract test suites composed of abstract test cases grouped in conformance classes and for defining the procedures to be followed during conformance testing*." Annex A of LADM Edition I and of each part of LADM Edition II, which specifies how to test whether a particular application schema, such as a country profile, is conformant with the LADM. The general approach of the conformance testing by ISO 19105:2022 is shown in Figure 2 (ISO, 2022a). It should be mentioned here that to develop an application schema for all parts of LADM Edition II, the guidance provided by *ISO 19106 Geographic information — Profiles* should be followed. ISO 19106:2004 defines "*the concept of a profile of the ISO geographic information standards developed by ISO/TC 211 and to provide guidance for the creation of such profiles.*" (ISO, 2004).

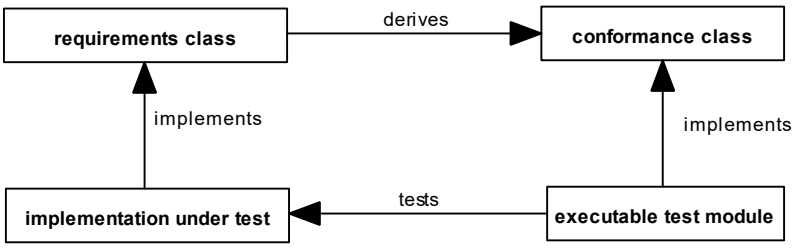


Figure 2. The general approach of the conformance testing of ISO 19105 (ISO, 2022a)

ISO 19107 Geographic information — Spatial schema is a crucial standard for LADM as it "*specifies conceptual schemas for describing the spatial characteristics of geographic entities, and a set of spatial operations consistent with these schemas. It treats "vector" geometry and topology.*" (ISO, 2019a). Part 1 uses this standard to represent geometric elements. However, since Part 1 does not contain detailed information about the spatial parts of LADM, in other words, since Part 1 does not include any attributes, operations or constraints other than the LA_Source and VersionedObject classes, the use of ISO 19107 in LADM is mentioned in the Part 2 section of this paper.

ISO 19109:2015 Geographic information — Rules for application schema define "*rules for creating and documenting application schemas, including principles for the definition of features.*" All LADM parts addressing land administration and georegulation (19152 series of standards) make use of the generic general feature model as described in ISO 19109 (ISO, 2015).

ISO 19115-1:2014 Geographic information — Metadata — Part 1: Fundamentals defines ISO "*the schema required for describing geographic information and services by means of metadata*" (ISO, 2014). LA_Source class is introduced to provide support for sources in land administration in Part 1. This class utilizes the ISO 19115-1 to represent responsible organization and responsible party of a source (i.e., CI_Responsibility), and type of document (i.e., CI_PresentationFormCode), see Figure 3.

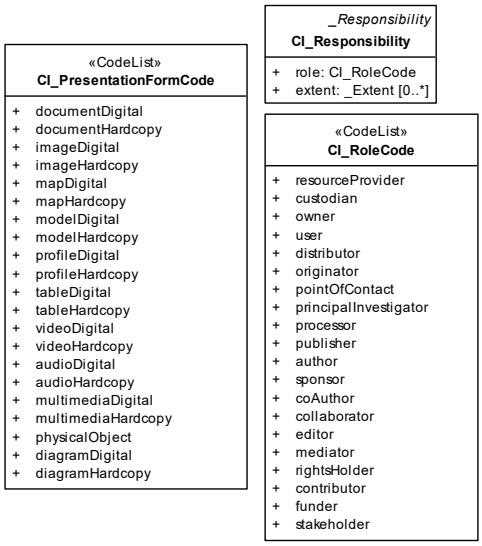


Figure 3. CI_Responsibility and CI_PresentationFormCode from 19115-1 (ISO, 2014)

The last standard referred in Part 1 is *ISO 19157-1:2023 Geographic information — Data quality — Part 1: General requirements*, which provides "*principles for describing the quality of geographic data*" (ISO 2023c). This standard is used in the data model of Part 1 to represent quality of a specific version of a source (i.e., QualityElement). LADM Edition I refers to ISO 19115:2003 for quality (i.e., DQ_Element), but quality information is now included in ISO 19157-1. For QualityElement and its subclasses (i.e., Completeness, LogicalConsistency, ThematicQuality, TemporalQuality, and PositionalAccuracy), see Figure 9 in the next subsection.

2.2 LADM Edition II Part 2

LADM Edition II Part 2 Land registration is based on Part 1. The terms and definitions used from other standards in the development of LADM Edition II Part 2 are listed in Table 3. As the Surveying and Representation subpackage of the Spatial Units package is introduced in Part 2, the terms referred to are related to geometric representations.

Table 3. Terms used from other standards in LADM Edition II Part 2

Standard	Term	Definition of the term
ISO 19107:2019	Boundary	Set that represents the limit of an entity
ISO 19107:2019	Face	2-dimensional topological primitive
ISO 19136:2020	Point	0-dimensional geometric primitive, representing a position

The standards and their relevant parts used in the development of the Part 2 data model are listed in Table 4. The standards in bold are the normative references in Part 2.

Table 4. Standards used in the LADM Edition II Part 1 data model and their relevant parts

Standard	Class
ISO 19103:2015 Geographic information — Conceptual schema language	CharacterString, Boolean, DateTime, Real, Integer, Area, Volume, Angle
ISO 19105:2022 Geographic information — Conformance and testing	- (Abstract test suite)
ISO 19106:2004 Geographic information — Profiles	- (Abstract test suite)
ISO 19107:2019 Geographic information — Spatial schema	Geometry, Point, Curve, Surface, PointCloud SetMask, DimensionExtension
ISO 19109:2015 Geographic information — Rules for application schema	- (General future model)
ISO 19111:2019 Geographic information — Referencing by coordinates	OperationMethod
ISO 19115-1:2014 Geographic information — Metadata — Part 1: Fundamentals	LI_Lineage
ISO 19156:2023 Geographic information — Observations, measurements and samples	Process
ISO 19157-1:2023 Geographic information — Data quality — Part 1: General requirements	AbsolutePositionalAccuracy
ISO 4217:2015 Codes for the representation of currencies	Currency
ISO/IEC 5218:2022 Information technology — Codes for the representation of human sexes	- (Sex types)
ISO 8601-2:2019 Date and time — Representations for information interchange — Part 2: Extensions	- (timeSpec)

ISO 20524-2:2020 Intelligent transport systems — Geographic Data Files (GDF) GDF5.1 — Part 2: Map data used in automated driving systems, Cooperative ITS, and multi-modal transport	- (timeSpec)
OGC Land and Infrastructure Conceptual Model Standard (LandInfra)	- (Surveying and representation subpackage)

ISO 19103 is utilized in Part 2 for CharacterString, Boolean, DateTime, Real and Integer classes, see Figure 1. Part 2, similar to Part 1, refers to ISO 19105 and ISO 19106 for profiling and testing the profile for compatibility with LADM. The general feature model of ISO 19109 has also been followed in the development of this part.

While LADM Edition I uses the 2003 version, LADM Edition II uses the 2019 version of the ISO 19107. One of the remarkable changes between these versions is that the definition of point is dropped from the last version; and ISO 19136-1:2020 became the authoritative source reference for point, which is defined as "*0-dimensional geometric primitive representing a position*" (ISO, 2020a). On the other hand, the class Point still included in ISO 19107:2019, see Figure 4. The class Point may look simple at first glance, but it is the start of a much larger part of the model where relevant LA functionality is available; including support for coordinate reference system (ISO, 2019a). The Point itself is an interface class that inherits from the Primitive interface class, which in turn inherits from Geometry interface class, see Figure 4. Of these three classes, only the interface class Point has an attribute of type (class) DirectPosition. It should be noted that that the Curve and Surface classes, as subclasses of the Orientable class, are also used in LADM to represent line and surface geometry, respectively.

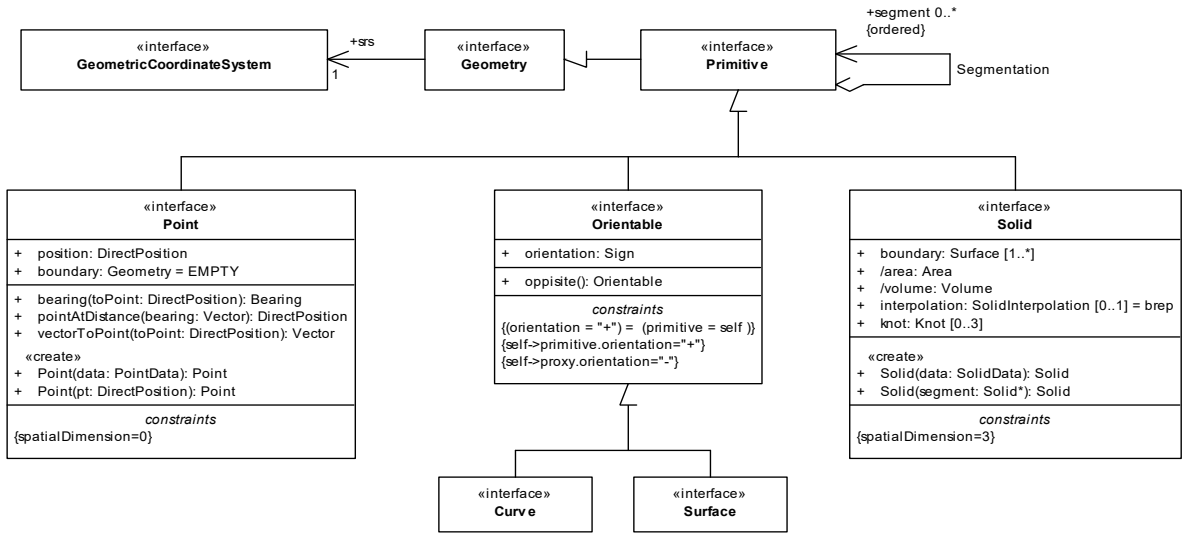


Figure 4. The Point, Curve and Surface geometries of ISO 19107 (ISO, 2019a)

ISO 19111:2019 Geographic information — Referencing by coordinates defines "*the conceptual schema for the description of referencing by coordinates.*" (ISO 2019a). The interface class CRS (Coordinate Reference System) has two specializations: the classes SingleCRS (again interface, with several interface subclasses, e.g., VerticalCRS, GeodeticCRS, DerivedCRS) and CompoundCRS (interface, an aggreagtion of SingleCRS);

see Figure 5. A SingleCRS is associated with one CoordinateSystem, which has in turn one or more CoordinateSystemAxis; see Figure 6. In summary, Point and CRS are part of a non-trivial model that should be able to provide all the functionality needed in the context of LADM (especially in the surveying and representation part): support for different coordinate systems and transformations.

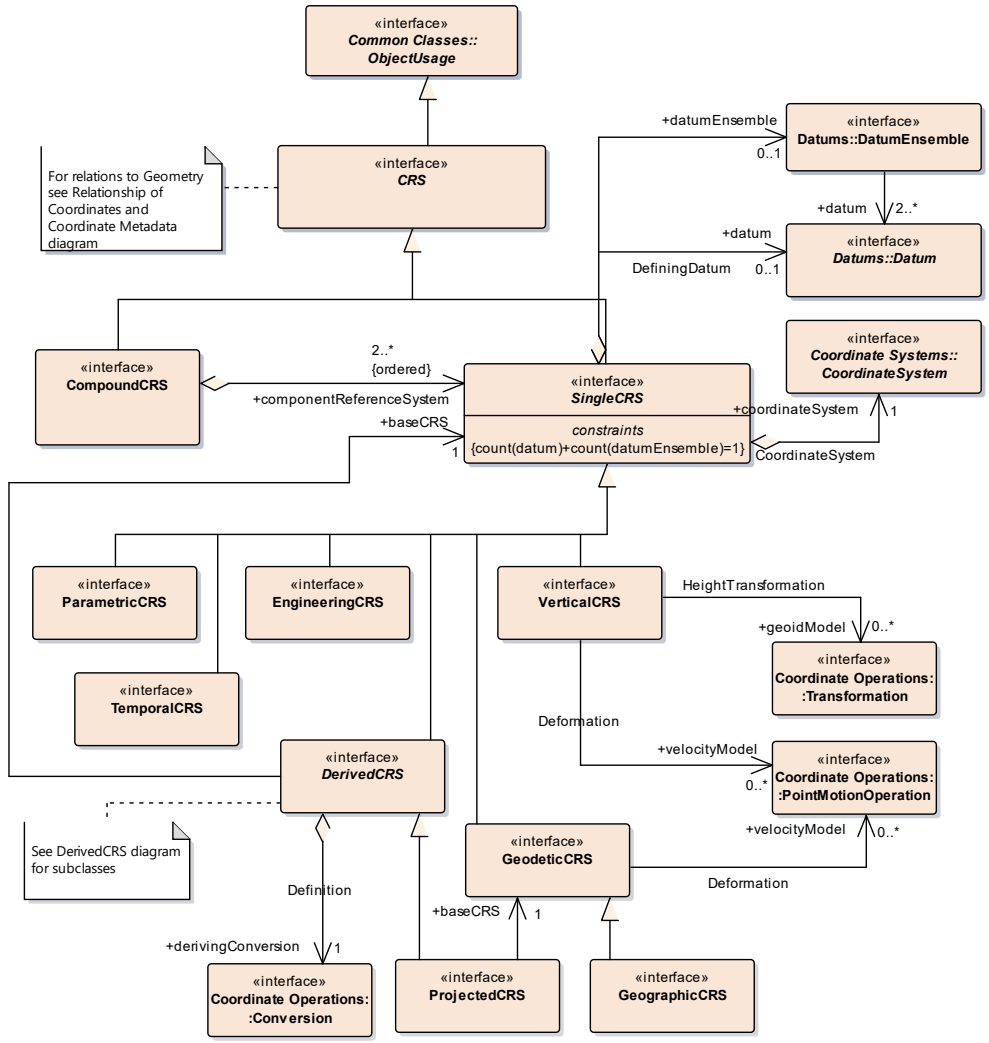


Figure 5. The class CRS (Coordinate Reference System) from ISO 19111 (ISO, 2019b)

The LI_Lineage class of ISO 19115-1 (ISO, 2014) used in the Part 2 data model to represent the lineage of the production method of a point instance. Figure 7 shows the LI_Lineage class and its associated classes (i.e., LI_ProcessStep, LI_Source and Abstract_LineageInformation) from ISO 19115-1 (ISO, 2014).

Another important ISO geographic information standard used in this document is ISO 19156, which defines "*a conceptual schema for observations, for features involved in the observation process, and for features involved in sampling when making observations*" (ISO, 2023b). The survey source data is modelled in Part 2 in LA_SurveySource which has the attribute

"procedure" is of type process and documents the actual survey procedure based on Procedure interface class of ISO 19156, see Figure 8 (ISO, 2023b).

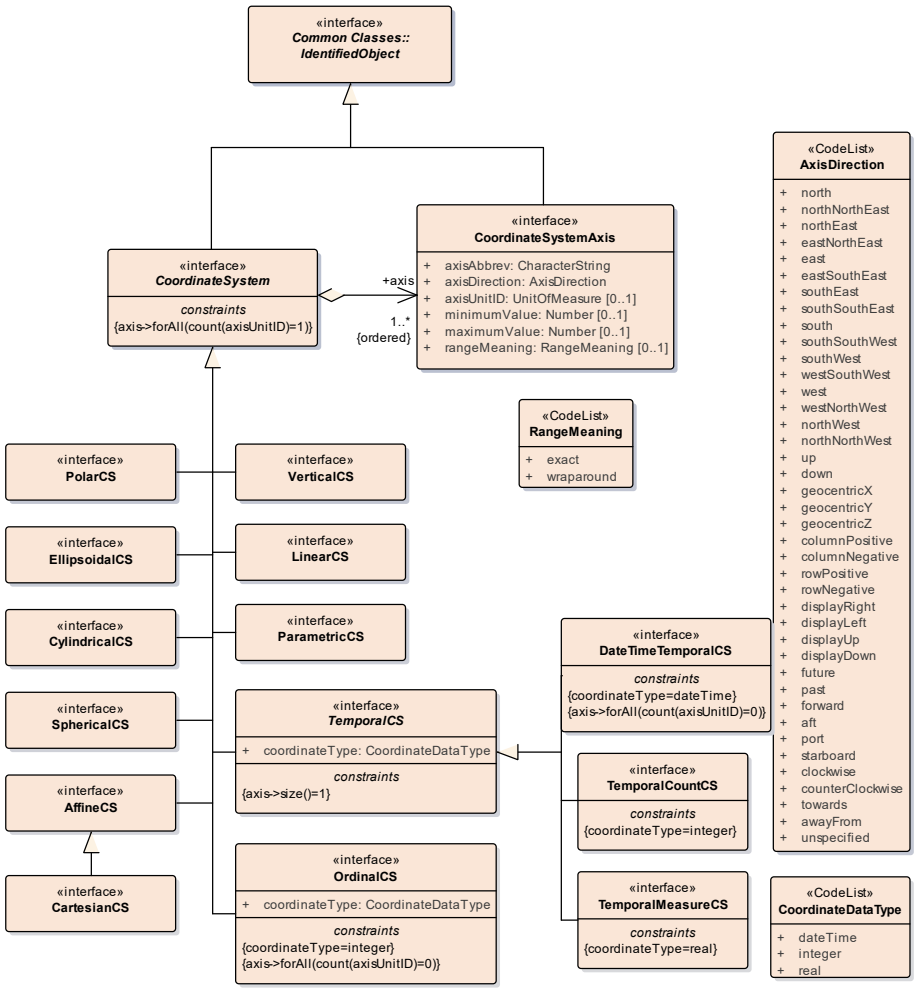


Figure 6. Coordinate system from ISO 19111 (ISO, 2019b)

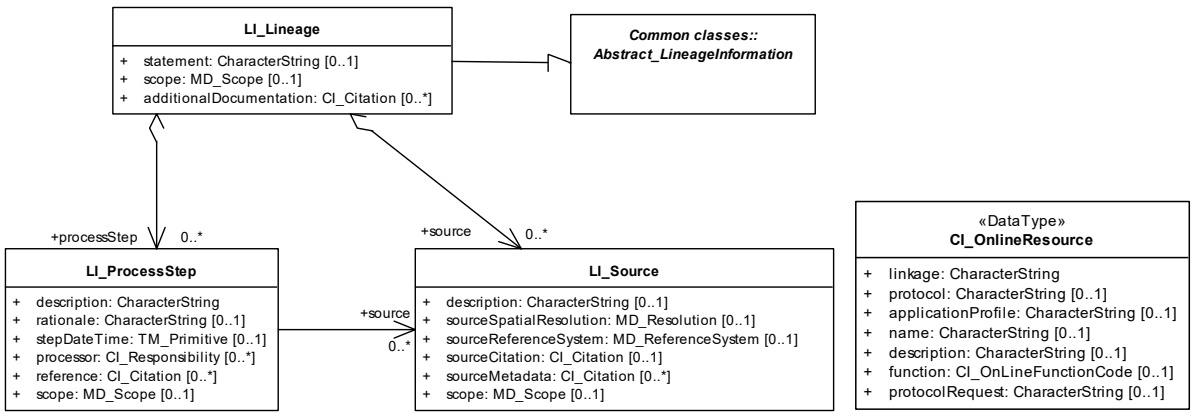


Figure 7. LI_Lineage (linked to Part 2) and CI_OnlineResource (linked to Part 3) classes from ISO 19115-1 (ISO, 2014)

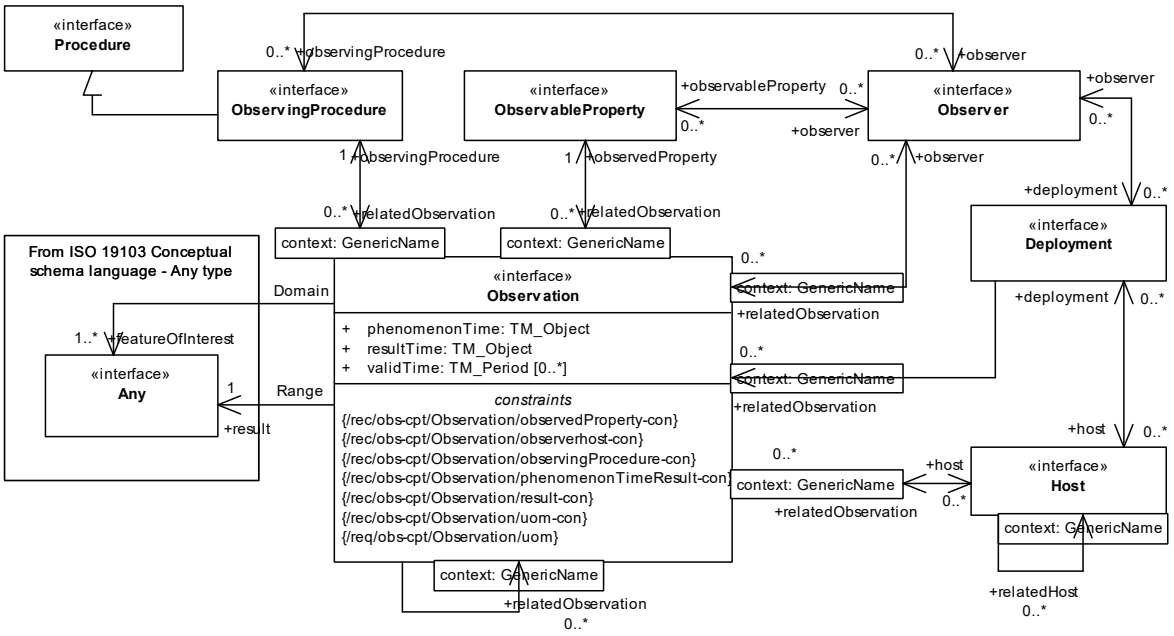


Figure 8. Observation from ISO 19156 (ISO, 2023b)

ISO 19157-1 utilized in Part 2 for representing absolute positional accuracy of a point instance. AbsolutePositionalAccuracy, which is a subclass of PositionalAccuracy, see Figure 9, is defined as "closeness of reported coordinate values to values accepted as true in a standard coordinate reference system" in the data model of ISO 19157-1 (ISO, 2023c).

The other standards that have been used in the development of Part 2 are those that have not been developed within ISO/TC 211. For example, *ISO 4217:2015 Codes for the representation of currencies* specifies "*the structure for a three-letter alphabetic code and an equivalent three-digit numeric code for the representation of currencies*" (ISO, 2015c). The amount attribute of the Part 2 LA_Mortgage class uses the codes specified in ISO 4217.

Supporting women's access to, use of and control over land in LADM Edition II, Part 2 is linked to *ISO/IEC 5218:2022 Information technology — Codes for the representation of human sexes* (Unger et al, 2021, 2023). This standard specifies "*a uniform representation of human sexes for the interchange of information*" (ISO/IEC, 2022). Part 2 creates a code list called LA_HumanSexesType, which includes the human sexes defined in ISO/IEC 5218: unknown, male, female and does not apply. It should also be noted that Part 2 is flexible enough to collect statistics on civil status and human sexes in support of UN SDG 5.

Attribute timeSpec of LA_RRR class of Part 2 is capable of handling other temporal descriptions, such as recurring patterns (every weekend, every summer, etc.). This means, for example, that a party can hold a right to use an apartment each year in March, or that a group of pastoralists has the right to cross a field each summer. In order to represent fuzzy time range specifications Part 2 is linked to *ISO 8601-2:2019 Date and time — Representations for information interchange — Part 2: Extensions* (ISO, 2019c) and *ISO 20524-2:2020*

Intelligent transport systems — Geographic Data Files (GDF) GDF5.1 — Part 2: Map data used in automated driving systems, Cooperative ITS, and multi-modal transport (ISO, 2020b).

Lastly, it should be mentioned that *OGC Land and Infrastructure Conceptual Model Standard* (LandInfra) (OGC, 2016) is used to refine the Surveying and Representation Subpackage of LADM Edition II Part 2, for details please see Kalogianni et al., (2021, 2023).

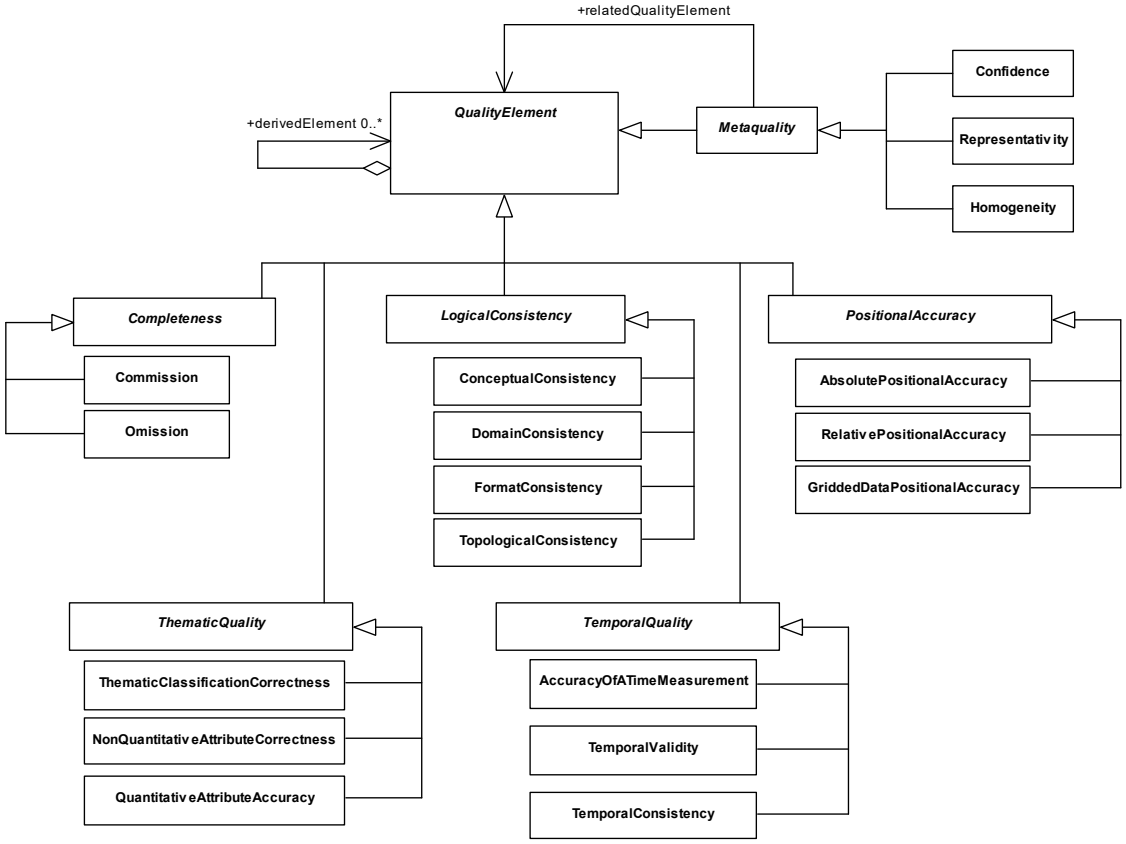


Figure 9. QualityElement from ISO 19157 (ISO 2023c)

LADM Edition II Part 2 contains annexes that present the relationships between this part of the standard and the other standards related to the land administration domain. Annex B of Part 2 mentions the Social Tenure Domain Model (STDM), which is a specialization of LADM (FIG/GLTN/UN-HABITAT, 2013). The LADM originated from areas with formal cadastral and land registration systems. It is noted that STDM includes most of the functionality of LADM, sometimes under different terminology. The normative Annex B reconciles the LADM class names with their aliases in STDM (ISO, 2012).

The informative Annex F presents the consistency between INSPIRE Data Specification on Cadastral Parcels (INSPIRE, 2014) and the LADM, by matching of concepts and compatible definitions of common concepts. To demonstrate compatibility, the LADM-based version of the INSPIRE cadastral parcels has been produced, explicitly showing how the INSPIRE development fits into the LADM and that there are no inconsistencies. (ISO, 2012).

Furthermore, the Annex K of Part 2 of LADM Edition II is established a link to OGC IndoorGML (OGC, 2019) to allow assigning rights, restrictions, and responsibilities to each indoor space to determine the accessible spaces for each type of party.

Finally, Annex L of Part 2 presents a case study for representing 3D legal spaces in buildings. This annex proposes terms and definitions refining 3D legal spaces in buildings based on the core concepts of LADM and Building Information Modelling (BIM) / Industry Foundation Class (IFC) (ISO, 2018) (Alattas et al., 2021).

2.3 LADM Edition II Part 3

LADM Edition II Part 3 Marine georegulation is a derived work, developed under a cooperative agreement with IHO based, on IHO standard S-121 and used with permission (ISO/DIS, 2023). The terms and definitions used in the development of LADM Edition II Part 3 are listed in Table 5.

Table 5. Terms and definitions used in LADM Edition II Part 3

Standard	Term	Definition of the term
ISO 19136-1:2020	Curve	1-dimensional geometric primitive, representing the continuous image of a line
IHO S-121 Maritime Limits and Boundaries (adopted)	Boundary	Delimitation between two or more zones
IHO S-121 Maritime Limits and Boundaries	Limit	Curve that defines a boundary or extent of a zone
IHO S-32 Hydrographic Dictionary	Marine	Relating to navigation or shipping or relating to or connected with the sea or used, or adopted for use at sea
IHO S-32 Hydrographic Dictionary	Maritime	Bordering on, or concerned with, or related to the sea

The standards and their relevant parts used in the development of the Part 3 data model are listed in Table 6. The standards in bold are the normative references in Part 3.

Table 6. Standards used in the LADM Edition II Part 3 data model and their relevant parts

Standard	Class
ISO 19152-1 Generic conceptual model	
ISO 19152-2 Land registration	
ISO 19103:2015 Geographic information — Conceptual schema language	DateTime, CharacterString, Integer, Boolean, Distance
ISO 19107:2019 Geographic information — Spatial schema	Geometry, Point, Orientable
ISO 19109:2015 Geographic information — Rules for application schema	- (General future model)
ISO 19110:2016 Geographic information — Methodology for feature cataloguing	- (Feature cataloguing)
ISO 19111:2019 Geographic information — Referencing by coordinates	CRS
ISO 19115-1:2014 Geographic information — Metadata — Part 1: Fundamentals	CI_Responsibility, CI_OnlineResource
ISO 19126:2021 Geographic information — Feature concept dictionaries and registers	- (Concept dictionary)
ISO 19131:2022 Geographic information — Data	- (Data production)

product specifications	
ISO 19135-1:2015 Geographic information — Procedures for item registration — Part 1: Fundamentals	- (Data registry)
ISO 19157-1:2023 Geographic information — Data quality — Part 1: General requirements	QualityElement

The normative references of Part 3 that are not mentioned in Part 1 and Part 2 are as follows: (a) *ISO 19110:2016 Geographic information — Methodology for feature cataloguing* defines "the methodology for cataloguing feature types (ISO, 2016), (b) *ISO 19126:2021 Geographic information — Feature concept dictionaries and registers* specifies "a schema for feature concept dictionaries to be established and managed as registers" (ISO, 2021), (c) *ISO 19131:2022 Geographic information — Data product specifications* describes "*requirements for the specification of geographic data products*" (ISO, 2022b), and (d) *ISO 19135-1:2015 Geographic information — Procedures for item registration — Part 1: Fundamentals* specifies "*procedures to be followed in establishing, maintaining, and publishing registers of unique, unambiguous, and permanent identifiers and meanings that are assigned to items of geographic information*" (ISO, 2015d).

According to the introduction section of ISO/DIS 19152-3 Marine georegulation (ISO/DIS, 2023), the International Hydrographic Organization (IHO)[1] supports standards development for oceanography, marine science and the UN SOLAS (UN, 1980) and UNCLOS (UN, 1982) conventions. IHO has developed a series of standards and specifications[2] that address the marine space. In particular the IHO standard S-121 on Maritime Limits and Boundaries (IHO, 2019). For their geographic information aspects, the IHO suite of hydrographic standards is based on the ISO ISO/TC 211 suite of Geographic Information standards, through the IHO Universal Hydrographic Data Model S-100 (IHO, 2018). The IHO S-121 standard on Maritime Limits and Boundaries directly supports the UNCLOS and is built upon the ISO 19152 LADM, more specifically LADM Edition II Part 3 is based on Part 1 and Part 2.

2.4 LADM Edition II Part 4

The LADM Edition II Part 4 Valuation information data model is based on the Part 1 and Part 2 data models. The terms and definitions from other standards and guidance documents used in the development of LADM Edition II Part 4 are listed in Table 7.

Table 7. Terms used from other standards and guidance documents in Part 4

Standard	Term	Definition of the term
ISO 6707-1:2020 Buildings and civil engineering works — Vocabulary — Part 1: General terms	Building	Construction works that is subject to a valuation that has the provision of shelter for its occupants or contents as one of its main purposes, usually partially or totally enclosed and designed to stand permanently in one place
OGC Land and Infrastructure Conceptual Model	Accessory part	Privately owned building part, generally attached to one or more condominium unit
	Condominium	Concurrent ownership of real property that has been divided

[1] International Hydrographic Organization: https://iho.int/
[2] IHO Standards, Specifications and Regulations: https://iho.int/en/standards-and-specifications

Standard (LandInfra)	unit	into private and common portions, and the privately owned part is made up of clearly demarcated parts of a building
UNECE Land Administration Guidelines with special reference to countries in transition	Market value	The most probable sale price of a real estate property in terms of money, assuming a competitive and open market
UNECE Land Administration in the UNECE Region: development trends and main principles	Sales comparison approach	Valuation of property based on estimates of the worth of similar properties
	Income approach	Valuation of property on the basis of its income stream
	Cost approach	Valuation of property based on estimates of costs
IAAO Standard on Mass Appraisal of Real Property	Mass appraisal	Process of valuing a group of properties as of a given date, using standard methods, employing common data, and allowing for statistical testing

The standards and their relevant parts used in the development of the Part 4 data model are listed in Table 8. The standards in bold are the normative references in Part 4.

Table 8. Standards used in the LADM Edition II Part 4 data model and their relevant parts

Standard	**Class**
ISO 19152-1 Generic conceptual model	
ISO 19152-2 Land registration	
ISO 19103:2015 Geographic information — Conceptual schema language	DateTime, CharacterString, Boolean, Integer, Decimal, Area, Volume
ISO 19105:2022 Geographic information — Conformance and testing	- (Abstract test suite)
ISO 19106:2004 Geographic information — Profiles	- (Abstract test suite)
ISO 19109:2015 Geographic information — Rules for application schema	- (General future model)
ISO 4217:2015 Codes for the representation of currencies	Currency
ISO 9836:2017 Performance standards in building — Definition and calculation of area and space indicators	- (Building area and volume types)
International Property Measurement Standards (IPMS): All buildings	- (Building area and volume types)
OGC Land and Infrastructure Conceptual Model Standard (LandInfra)	- (Condominium unit and condominium building)

The references of Part 4 that are not mentioned in Part 1, Part 2 and Part 3 are as follows: *ISO 9836:2017 Performance standards in building — Definition and calculation of area and space indicators* specifies "*the definition and calculation of surface area and volume indicators*" (ISO, 2017). Similarly, International Property Measurement Standards (IPMS): All buildings (IPMSC, 2023) provides "*the foundation for incorporation into and adoption of building measurement conventions in global jurisdiction*[3]". These standards are used to structure VM_BuildingAreaType and VM_BuildingVolumeType code lists. The OGC Land and Infrastructure Conceptual Model Standard (LandInfra) (OGC, 2016) is utilized to model

[3] The International Property Measurement Standard (IPMS) https://ipmsc.org/

condominium unit and building parts of the data model of Part 4. Finally, it should also be noted that numerous terms and definitions at attribute level and code list value level, which may be changed/revised during the project team meetings, are adapted from international valuation standards during the development of Part 4, for more detailed information see Çağdaş et al. (2017).

2.5 LADM Edition II Part 5

The LADM Edition II Part 5 Spatial plan information data model is based on the Part 1 and Part 2 data models. The standards, terms and definitions used in the development of LADM Edition II Part 5 are listed in Table 9.

Table 9. Terms used from other documents in LADM Edition II Part 5

Standard	Term	Definition of the term
INSPIRE Planned Land Use	Spatial plan	A set of documents that indicates a strategic direction for the development of a given geographic area, states the policies, priorities, programmes and land allocations that will implement the strategic direction and influences the distribution of people and activities in spaces of various scales
European Commission	spatial planning	Methods used largely by the public sector to influence the future distribution of activities in space

The standards and their relevant parts used in the development of the Part 5 data model are listed in Table 10. The standards in bold are the normative references in Part 5.

Table 10. Standards used in the LADM Edition II Part 5 data model and their relevant parts

Standard	Class
ISO 19152-1 Generic conceptual model	
ISO 19152-2 Land registration	
ISO 19103:2015 Geographic information — Conceptual schema language	DateTime, CharacterString, Integer, Area, Volume,
ISO 19105:2022 Geographic information — Conformance and testing	- (Abstract test suite)
ISO 19106:2004 Geographic information — Profiles	- (Abstract test suite)
ISO 19107:2019 Geographic information — Spatial schema	Point
ISO 19109:2015 Geographic information — Rules for application schema	- (General future model)

Part 5 is developed/influenced by the Plan4all project which was initiated to focus on the harmonization of spatial planning data based on the best practices in EU member countries for seven themes (i.e., land cover; land use; utility and government services; production and industrial facilities; agricultural and aquaculture facilities; area management/restriction/ regulation zones, and reporting units; natural risk zones) (Cerba, 2010). The Part 5 may promote interoperability through the integration of outputs of spatial planning processes with land registry and cadastre.

3. LADM AND INTERNATIONAL GUIDELINES AND FRAMEWORKS

LADM Edition I is based on the principles of Cadastre 2014 (Kaufmann and Steudler, 1998; Steudler 2014), and a number of standards, in particular those published by ISO/TC 211 and, of course, other committees. Since LADM Edition II is designed as backwards compatible with LADM Edition I, LADM Edition II is also based on the principles of Cadastre 2014. It should be noted that the principle of legal independence from Cadastre 2014 can be implemented with complete separate LADM implementations of Cadastre 2014 per layer or with only the spatial unit package of LADM per layer.

Both LADM Edition I and LADM Edition II are based on the continuum of land tenure/rights principle as specified in the Secure Land Rights for All (UN-HABITAT, 2008) and assessed in the Framework for Evaluating Continuum of Land Rights Scenarios (UN-HABITAT/GLTN, 2016). The former one argues that "*policymakers should adopt and implement the continuum of land rights because, no single form of tenure can meet the different needs of all social groups. However, a range of land tenure options enables both women and men from all social groups to meet their changing needs over time*." The latter one describes the continuum of land rights as "*a situation (a continuum of land rights scenario) where, in a particular country, region or area, different tenure forms incorporating a range of interests exist simultaneously*" and provides a framework for evaluating land in continuum of land rights scenario. The first requirement of LADM Edition II Part 2 is about the continuum of land rights and it reads as follows: "*The Triple Object (Spatial Unit) – Right (RRR) – Subject (Party) shall be the common pattern and the basic structure for LA. Groupings of objects or subjects should be supported. The flexibility of LA model should be based on the recognition that people's land relationships appear in many different ways, depending on local tradition, culture, religion and behaviour*." It should be mentioned that a quite similar requirement is also followed in developing LADM Edition I, see Lemmen et al. (2015).

After publication of LADM Edition I, it has been implemented by various organizations. GLTN developed STDM, which is a specialization of LADM, and STDM software[4]. IHO developed S-121 based on LADM. On the other hand, the terms specified by the IPMS: All Buildings standard (IPMSC, 2023) are used to represent building floor areas in LADM Edition II. Similar approaches can be followed to implement guidance documents and frameworks. This, of course, fits very well into the context of the implementation of the Sustainable Development Goals (SDGs). With the recent advancements represented by LADM Edition II, which includes critical components such as land value, land use and marine geo-regulation, the model has the potential to support multiple SDGs. It aligns with SDGs 1 (no poverty), 2 (zero hunger), 5 (gender equality), 8 (decent work and economic growth), 9 (industry, innovation and infrastructure), 11 (sustainable cities and communities), 14 (life below water) and 15 (life on land), as assessed by ISO/TC 211. In addition, Land Parcels are determined as one of the 14 global fundamental geospatial data themes by UN-GGIM (UN-GGIM, 2019). According to this data theme, land parcels are a powerful governmental tool to achieve many SDGs, including 1.4, 2.4, 8, and 11.1 (UN-GGIM, 2019). It should be noted that UNGGIM Land Parcels data theme recognizes ISO 19152:2012 LADM as existing

[4] Social Tenure Domain Model: https://stdm.gltn.net/

geospatial data standards on land parcels together with INSPIRE Data Specification on Cadastral Parcels (INSPIRE, 2014) and International Land Measurement Standard (ILMS) (ILMSC, 2019).

LADM Edition II can also be utilized to implement various clauses of the New Urban Agenda (UN, 2016), such as:

- "*… The use of digital platforms and tools, including geospatial information systems, will be encouraged to improve long-term integrated urban and territorial planning and design, land administration and management, and access to urban and metropolitan services*." (cf. Clause 156),
- "*We will promote compliance with legal requirements through strong, inclusive management frameworks and accountable institutions that deal with land registration and governance, applying transparent and sustainable management and use of land, property registration and sound financial systems. We will support local governments and relevant stakeholders, through a variety of mechanisms, in developing and using basic land inventory information, such as cadastres, valuation and risk maps, and land and housing price records, to generate the high-quality, timely and reliable data — disaggregated by income, sex, age, race, ethnicity, migration status, disability, geographic location and other characteristics relevant in the national context — needed to assess changes in land values, while ensuring that these data will not be used for discriminatory land-use policies.*" (cf. Clause 104),
- "*We will support appropriate policies and capacities that enable subnational and local governments to register and expand their potential revenue base, for example, through multipurpose cadastres, local taxes, fees and service charges, in line with national policies, while ensuring that women and girls, children and youth, older persons, persons with disabilities, indigenous peoples and local communities, and poor households are not disproportionately affected*." (cf. Clause 134)
- "*We will support science, research and innovation, including a focus on social, technological, digital and nature-based innovation, robust science-policy interfaces in urban and territorial planning and policy formulation and institutionalized mechanisms for sharing and exchanging information, knowledge and expertise, including the collection, analysis, standardization and dissemination of geographically based, community-collected, high-quality, timely and reliable data disaggregated by income, sex, age, race, ethnicity, migration status, disability, geographic location and other characteristics relevant in national, subnational and local contexts*." (cf. Clause 157)

The Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security (VGGT) (FAO, 2012) set out "*principles and internationally accepted standards of responsible practices for the use and control of land, fisheries and forests. They provide guidance for improving the policy, legal and organizational frameworks that regulate tenure rights; for enhancing the transparency and*

administration of tenure systems.[5]" The implementation of various clauses in VGGT can be achieved through the LADM compatible profiles, such as:

- "*States should provide systems (such as registration, cadastre and licensing systems) to record individual and collective tenure rights in order to improve security of tenure rights, including those held by the State and public sector, private sector, and indigenous peoples and other communities with customary tenure systems*" (Clause 17.1).
- "*States should ensure that appropriate systems are used for the fair and timely valuation of tenure rights for specific purposes, such as operation of markets, security for loans, transactions in tenure rights as a result of investments, expropriation and taxation. Such systems should promote broader social, economic, environmental and sustainable development objectives*." (Clause 18.1).
- "*Regulated spatial planning affects tenure rights by legally constraining their use. States should conduct regulated spatial planning, and monitor and enforce compliance with those plans, including balanced and sustainable territorial development, in a way that promotes the objectives of these Guidelines. In this regard, spatial planning should reconcile and harmonize different objectives of the use of land, fisheries and forests*." (Clause 20.1).

The relevant parts of LADM can also be used to implement Fit-For-Purpose Land Administration (FFPLA) principles (FIG/World Bank, 2013), such as:

- "*General boundaries rather than fixed boundaries*" (LADM supports both approaches),
- "*Aerial imageries rather than field surveys*" (LADM supports both approaches),

It is worth noting that the FFPLA (FIG/World Bank, 2013) refers to LADM and STDM as follows: "*The STDM is a sub-version of the new ISO standard on Land Administration Domain Model (ISO 19152, 2012) that presents a generic and inclusive solution as a way forward for building flexible land administration systems*." In addition, Fit-for-Purpose Land Administration: Guiding principles for country implementation (UNHabitat/GLTN/Kadaster, 2016) also refers to LADM as follows: "*In order to assure an easy and adaptable interoperability layer with other stakeholders, the data model chosen for the FFP Land Administration system should be based on (ISO 19152:2012) - Land Administration Domain Model (LADM) and the derived Social Tenure Domain Model (STDM)*.

Another document that referred to LADM is the UN-GGIM Expert Group on Land Administration and Management's Framework for Effective Land Administration A reference for developing, reforming, renewing, strengthening or modernizing land administration and management systems (UN-GGIM, 2020). This framework specifies a number of qualities (e.g., (a) "*land data and land processes should be appropriate, accessible, affordable and integratable with other data organized under the UN Global Fundamental Geospatial Data Themes*", (b) "*land data may be gathered from a wide range of sources, scales and sensors - but, in all cases, should generally deliver its metadata and enable standardized identification*

[5] Responsible Governance of Tenure: https://www.fao.org/policy-support/tools-and-publications/resources-details/en/c/416990/

of the spatial extent, time period, and people to which the right, restriction or responsibility pertains to" and (c) "*Availability, accessibility, and interoperability of the land data are*" required) that are necessities for effective land administration. According to this framework, LADM and IHO S-121 provide starting points for creating these qualities (UN-GGIM, 2020). Furthermore, STDM is also recognized in this framework: "*The Land Administration Domain Model (ISO 19152) provides an ISO endorsed data model whereas the Social Tenure Domain Model (STDM), in Annex I of the LADM, provides a concept and data model to record all people to land relationships. ISO/TC211 is working on the second edition of LADM. The IHO S-121 standard focuses on maritime limits and boundaries.*"

LADM is also cited in the Addis Ababa Declaration Geospatial Information Management Towards Good Land Governance for the 2030 Agenda as follows: "develop and agree on a set of fundamental geospatial information elements for land governance as a subset of the UN-GGIM fundamental data themes aligned with the SDG global indicator framework, taking into account the ISO 19152 Land Administration Domain Model and progress in multi-dimensional cadastre and city models" (UN-GGIM, 2016).

Finally, the ILMS is a framework to enable the reporting process of due diligence (meaning an assessment that is considered reasonable and practicable in the environment in which the ILMS instruction is being carried out) on land and property matters for people and legal entities (ILMSC, 2019). The definition section of the ILMS defines the LADM, but it is not cited in the main text. Kavanagh et al. (2021) state that ILMS and LADM can feed into each other and can be integrated.

4. CONCLUSION

Sustainable and interoperable data management requires the use of existing standards wherever possible. LADM Edition II has been developed with this principle in mind. It is linked not only to ISO/TC 211 standards, but also to standards published by other ISO committees, as well as OGC, IFC/BIM, IHO and so on. It should be noted that since no part of LADM Edition II is now an international standard, the linked standards may be subject to change.

The purpose of this paper is to document which standards LADM Edition II is based on and associated with, and which guidelines and frameworks are in some way related to LADM. A brief description of the standards and their relevant definitions and classes that have been used in the development of the first five parts of LADM Edition II is organized in this paper. It is clear that the LADM data model is not only based on many standards, but also references and can be used to implement many guidelines and frameworks on land administration.

It is expected that LADM Edition II Part 6 will also be based on several different standards as one of its focuses is on LA processes. It is anticipated that Part 6 may include detailed information on the integration/implementation of IPMS and ILMS with LADM as they include processes for area measurement and reporting, respectively.

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BIOGRAPHICAL NOTES

Abdullah Kara holds a Ph.D. degree from Yıldız Technical University (YTU) with a thesis on the extension of Land Administration Domain Model (LADM) with valuation information, which is used as a basis for the development of LADM Part 4 - Valuation information. He is currently working as a post-doctoral researcher at the GIS Technology Section, Delft University of Technology. He has been actively involved in FIG working groups.

Eva-Maria Unger works with the international arm of the Netherlands national mapping, land registration and cadastral agency (Kadaster International) as a Senior Land Administration Advisor. She gives advice, assessments, designs and oversees the conceptualisation and implementation of affordable and effective land administration systems. She is responsible for developing deeper relationships with international donors, partner countries and other consultants. She is co-editor of the UN GGIM Framework on Effective Land Administration. Dr. Unger completed a secondment with UN-GGIM while still being employed by the Kadaster. She holds an MSc. in Geodesy and Geoinformation, and a PhD in Land Administration. As a researcher Eva-Maria is involved in teaching at KU Leuven and University of Twente. Eva-Maria was chair of the FIG Young Surveyors Network from 20142018 dedicated to the STDM Training of Trainers Program and initiator of the Volunteer Community Surveyors Program (VCSP) supporting the GLTN's county-level implementation plans and programmes.

Peter van Oosterom obtained an MSc in Technical Computer Science in 1985 from Delft University of Technology, the Netherlands. In 1990 he received a PhD from Leiden University. From 1985 until 1995 he worked at the TNO-FEL laboratory in The Hague. From 1995 until 2000 he was senior information manager at the Dutch Cadastre, where he was involved in the renewal of the Cadastral database. Since 2000, he is Professor at Delft University of Technology, and head of the 'GIS Technology' Chair, Digital Technologies Section, Faculty of Architecture and the Built Environment, Delft University of Technology, the Netherlands. He is the current chair of the FIG Working Group on '3D Cadastres' and co-editor of the International Standard for Land Administration Domain, ISO 19152.

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Analysing 3D Land Administration developments and plans from 2010 to 2026

Rod THOMPSON, Australia, Eftychia KALOGIANNI and Peter VAN OOSTEROM, the Netherlands

Key words: LADM, ISO19152, Questionnaire, Land Administration, 3D Cadastre trends, assessment rubric

SUMMARY

This paper is the follow-up of 4 earlier analysis papers on the 3D Cadastres / Land Administration questionnaires. The last FIG questionnaire 2022-2026 was just analysed and the FIG working week 2023 (Kalogianni et al. 2023, and in that paper the creation or update, organization and initial analysis of the results from the 4th FIG 3D Land Administration Questionnaire, as an activity of the FIG Working Group 3D Land Administration 2022-2026 was presented. By sharing this information among the countries/ jurisdictions, a comprehensive inventory will be created. It is expected that cooperation will improve, by learning from the different countries and jurisdictions, to support future developments in the field of 3D land administration. It is noted that, as LADM is finding increasing recognition (Kalogianni et al., 2021), it has been further incorporated into the various sections of the questionnaire.

The completed questionnaires, per country are fully available via the participants' page of the 3D Land Administration Working Group website. The responses have been analyzed and reported in various publications (van Oosterom et al. 2011, van Oosterom et al. 2014 and Shnaidman et al., 2019), while the initial analysis of the 4th Questionnaire has been recently presented by Kalogianni et al. (2023).

This paper aims to provide an overview of the developments and plans from the initial questionnaire in 2010, till the future plans for 2026, based on the analyses that have been previously carried out (van Oosterom et al. 2011, van Oosterom et al. 2014 and Shnaidman et al., 2019) and highlighting the results of the analysis from the latest questionnaire. The initial results from the latest questionnaire have been presented by Kalogianni et al. (2023), providing the main outcome from the current status (December 2022), while highlighting the priority axes till 2026 related to the developments of 3D LAS.

What is more, an assessment rubric is developed by the team that prepares and analyses the questionnaires, that is actually a scoring of the responses in the various sections of the four (4) questionnaires This assessment process is the first time that is being carried out and it is executed for eight (8) countries and presented in this paper.

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1. INTRODUCTION

An efficient and reliable land administration system is the foundation for a strong economy of a country and sustainable development. Since cadastre is perceived as the core of any land administration system, linking the three essential components therefrom: people-to-land relationships through Rights/Restrictions/Responsibilities (RRRs), it is expected to provide a complete and up-to-date information regarding parcels boundaries and the associated relations (Kitsakis et al., 2018).

The majority of currently operational land administration systems around the world are 2D-based, while there are various countries/ jurisdictions that have developed operational components of 3D LAS and in parallel, the topic has been the subject of much research and debate (Lemmen et al., 2003; van Oosterom, 2013; van Oosterom, 2018, van Oosterom, 2022). Part of this activity was coordinated and supported by the international community of surveyors, namely the International Federation of Surveyors (FIG) Joint Commission 3 and 7 Working Group on "3D Cadastres". It is noted that at the FIG Working Week 2023 in Florida, the new name of the FIG Working Group was decided to change in order to include LADM (ISO 19152, the Land Administration Domain Model) and has been formed as "Land Administration Domain Model/ 3D Land Administration"; in short, "LADM/ 3D LA".

The Questionnaires on 3D Cadastres have been conducted three times by the Working Group, in 2010, 2014 and 2018, while the 4th Questionnaire on 3D Land Administration is conducted as a successor of the previous three questionnaires and presents the status of December 2022. The original structure and numbering of the questions as introduced at the first edition of the questionnaire (2010), have been carefully maintained, while specific questions were altered over time, where needed from 2010 to 2022, to provide a better understanding of the questions to the responders. By sharing this information among the countries/ jurisdictions, a comprehensive inventory will be created. It is expected that cooperation will improve, by learning from the different countries and jurisdictions, to support future developments in the field of 3D land administration. It is noted that, as LADM is finding increasing recognition (Kalogianni et al., 2021), it has been further incorporated into the various sections of the questionnaire.

This paper aims to provide an overview of the developments and plans from the initial questionnaire in 2010, till the future plans for 2026, based on the analyses that have been previously carried out (van Oosterom et al. 2011, van Oosterom et al. 2014 and Shnaidman et al., 2019) and highlighting the results of the analysis from the latest questionnaire. The initial results from the latest questionnaire have been presented by Kalogianni et al. (2023),

providing the main outcome from the current status (December 2022), while highlighting the priority axes till 2026 related to the developments of 3D LAS. What is more, an assessment rubric is developed by the team that prepares and analyses the questionnaires, that is actually a scoring of the responses in the various sections of the four (4) questionnaires This assessment process is the first time that is being carried out and it is executed for eight (8) countries and presented in this paper.

The rest of the paper is structured as follows: Section 2 reflects on the structure and context of the four questionnaires and their evolution from 2010 till today, while providing more insights on the results of the last edition of the questionnaire. Moreover, Section 3 provides a rubric to assess the countries/ jurisdictions based on their answers at the various questions of the questionnaire and provides the initial results for seven countries aiming to initiate the discussion in this field. Finally, the last Section is devoted to discussion and next steps of this research.

2. STRUCTURE AND ORGANISATION OF THE FIG 3D LAND ADMINISTRATION QUESTIONNAIRES FROM 2010 TO 2022

A brief reflection on the structure and organization of the four questionnaires that have been developed till today is presented in Sub-section 2.1, providing the basis for constructive conclusions in Section 3. Furthermore, the main conclusions drawn from the last questionnaire regarding the status of 3D LAS at the end of 2022 related to LADM and the plans and priorities of the countries for the coming four (4) years are presented in Sub-section 2.2.

2.1 FIG 3D Land Administration Questionnaires from 2010 to 2022

The questionnaire, from its first edition, aims to address the most important aspects related to 3D LAS and it occurs every four (4) years, so that important technological developments and advances in the legal aspects can be reported per country. As already mentioned, the structure and numbering of the questions as introduced at the first edition of the questionnaire (2010), have been carefully maintained, while specific questions were altered over time and also added. Specifically, the first edition of the questionnaire comprised ten (10) sections, while the other three sections comprised thirteen (13) sections.

In all editions, the first nine (9) sections and the last one (Other Issues – referring to the contact details of the responders) remain the same, with differences in the number of questions. The first nine sections are:

- Section 1. - General/ applicable 3D real-world situations
- Section 2. - Infrastructure/ Utility Networks
- Section 3. - Construction/ Building Units
- Section 4. – X/ Y Coordinates
- Section 5. - Representation of 3rd dimension: height (or depth)
- Section 6. - Temporal issues (4th dimension)

- Section 7. - Rights, Restrictions and Responsibilities (RRRs)
- Section 8. - The Cadastral Database (Digital Cadastral Database - DCDB)
- Section 9. - Plans of survey (including field sketches)

What is more, some questions are reshaped or, where necessary additional information is provided, to stipulate a better understanding to the responders. This was the case especially, at the second edition of the questionnaire, where it has been noticed that some questions in the first questionnaire were ambiguous to the responders, as most of the countries could provide the same answer. This is caused by the fact that terms may have slightly different meaning in different countries around the world, which is especially true for more abstract concepts such as 3D Cadastre and 3D parcel, while the level of expertise of the responders influence the responses. Therefore, one of the biggest changes in the second edition of the questionnaire was that the LADM was explicitly referred as basis for the used terminology, while a few notes (including an informal and a formal definition of a 3D parcel) were added. Moreover, some example answers and completed questionnaires (for Queensland and The Netherlands) were provided, without trying to be leading.

From the Sections' perspective, the topics of dissemination of 3D LA-related information (Section 10.) and the provision of statistical information (Section 11.) from the countries have been added in 2014 and are maintained till the last edition of the questionnaire, while the section of the reflection (Section 12.), introduced in the second edition of the questionnaire with five (5) questions, has been enriched after the third edition. As a result of the rapid development of the 3D LA advances worldwide, the aspects introduced in this section refer to pilots' execution in the field of 3D LA, as well as the advances in the legislative framework. It is worth noting that due to new developments and context, significant modifications within the questionnaires' context are found in Section 1, Section 3, Section 7 and 9, mostly lying on the inclusion of new questions that arise from the top trends on the 3D LA domain, as well as the wider scope of the LADM Edition II. Finally, there are nineteen (19) countries/ jurisdictions that have participated in all four (4) questionnaires till now.

2.2 Status of 3D LAS around the world in 2022 related to LADM and key challenges for the coming four years

All members/ countries of the FIG 3D LA & LADM WG have been requested to provide information both regarding the current situation at the end of 2022 and the expectations/ plans for 2026. This current questionnaire is backwards compatible with the previous three, while some questions have been refined for clarification and several new questions have been added at the end of the sections, introducing the topics of BIM in land administration, 3D land administration applications and implementation of the LADM.

The new questions introduced in this questionnaire aim to provide more insight about the following aspects:

- developments related to ISO19152 LADM, specifically related to country profiles;
- BIM-based sources used for 3D LAS registration and relevant specifications that may apply to the country;
- operational solutions related to previous question;

- developments related to national 3D City Models and
- other types of objects that require both real-world time and database time to be registered at the LAS.

In total, thirty-seven (37) countries responded to the Questionnaire in 2022, from which four (4) are new participants (did not participated before). In terms of consistency, there are also four (4) countries that have participated in the previous three (3) questionnaires, but not at the current one.

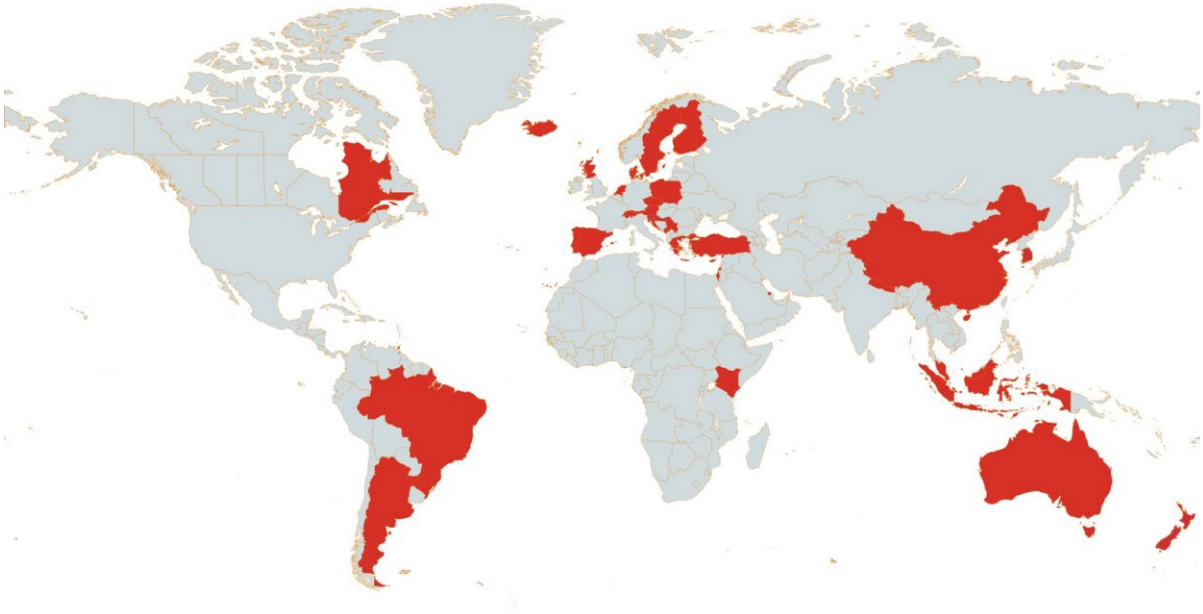


Figure 1. Spatial distribution per continent of the countries that have participated in the 4th Questionnaire of 3D Land Administration (current status of 2022 and expectations for 2026) (Kalogianni et al., 2023).

Regarding the use of ISO19152:2012 LADM as a formal model for the 3D parcels currently (end of 2022), four (4) countries answered positively (Shenzhen in China, Finland, Malaysia and Scotland), while Singapore mentioned that this is under investigation and Sweden that LADM is being used conceptually. It is worth noting, that 35% of the responders declared that their cadastral database is based on LADM. This answer has many aspects, to be further analysed, as there were answers that declared that the database is partly or fully compliant with LADM, or not explicitly mapped with LADM concepts, or that this is achieved using particular software tools, so the level of compliance relies on those (i.e. Trinidad and Tobago uses Trimble Landfolio). In this light, there are ten (10) countries that responded positively in the question of considering adopting LADM till 2026.

Almost half of the countries (49%) that have participated in the questionnaire have not currently developed a country profile based on LADM. From those that have developed, a 41% declares that the country profile has either been developed at a preliminary stage (i.e. mapping between LADM classes and the respective LAS concepts), or it has been developed by academia and can be accessed through relevant publications. Twenty-four (24) countries provided data about the future plans for 2026, and their priorities can be organized in three categories as follows:

- **Legal aspects:** provision of legislation that can support 3D in land administration; raise awareness on the legal community (lawyers, notaries, etc.) about the advantages of 3D LA; convince government that 3D is needed and shall invest on it.
- **Organisational aspects:** capacity building on the personnel and support for reform (including training) to be able to handle 3D LAS; engagement of private sector and stakeholders and their involvement in the development of clear guidelines; cultural shift towards 3D LA from government, organisations and professionals.
- **Technical aspects:** software development in line with the latest 3D developments; usage of the latest technologies; interoperability between data and systems; support/ guidelines for 3D capture, management and dissemination of the surveying-related information; digital submission of (surveying) information.

3. INITIAL ASSESSMENT RUBRIC FOR THE EVALUATION OF THE RESPONDERS

An assessment rubric for the FIG Questionnaire on 3D Land Administration is presented in Sub-section 3.1, providing scoring for the responses in the various sections of the questionnaire. Furthermore, this is used to provide the scoring, using the average Manhattan Distance computed, for 6 countries for their responses at the four questionnaires from 2010 till 2022 (Sub-section 3.2).

3.1 Assessment rubric for the FIG Questionnaire on 3D Land Administration

Based on the analysis of the results of the responses from the 4th FIG Questionnaire on *3D Land Administration*, an initial attempt to create an assessment rubric to evaluate the countries is developed and presented in this section. As presented in the following table, for nine (9) sections of the questionnaire a scoring method is developed. For Section 4 related to the (X, Y) coordinates the respective scoring method was developed, but following the overall assessment it appears to be less useful and hence it is not included in the overall evaluation, while the last two sections concerning country's overall reflection and the contact details of the responder are excluded, as they do not provide information that can be assessed.

Table 1. Rubric assessment for the FIG Questionnaire on 3D Land Administration

Scoring	Description
SECTION 1 - GENERAL/ APPLICABLE 3D REAL-WORLD SITUATIONS	
0	3D spatial units are not recognised
2	3D spatial units recognised, but not as part of Cadastre/ LAS (with different legal system from 2D)
4	Legislation existing for 3D spatial units
6	Strata units and common property are recognised
8	Fully general 3D volumes are treated as first-class cadastral objects
10	Full LADM based support of 3D volumes.
SECTION 2 - INFRASTRUCTURE/ UTILITY NETWORKS	

0	Utility networks not recognised
2	Networks recognised but not as part of Cadastre/ LAS
4	Jurisdiction has privately owned/leased, etc. networks within Cadastre/ LAS
5	Networks recorded (within Cadastre/ LAS) in 2D
6	Networks are fully defined in 3D
8	Network sections are first-class cadastral objects
10	Full LADM based support of network objects
SECTION 3. - CONSTRUCTION/ BUILDING UNITS (including spatial extents of units defined in 3D by physical walls/objects)	
0	Units/apartments/construction units are not recognised
2	Units/apartments/construction units are recognised but not as parts of Cadastre/ LAS
4	Special legislation for 3D units, etc. exists
5	Meaning of boundaries is defined (middle of wall, etc.)
6	Full definition of buildings including common property
7[1]	Tenure is fully defined on units (protection against sale of 2D parcel)
8	Units are a first-class cadastral object
9[2]	BIM is mandated for registration of units in certain classes of buildings
10	BIM is mandated for registration of all units
SECTION 5. - REPRESENTATION OF 3rd DIMENSION: HEIGHT (OR DEPTH)	
0	No ground surface model or definition of 2D parcel elevations exists
2	2D parcels are defined in relation to local ground level, but not quantified
4	Jurisdictional height datum exists and is referenced
6	Ground surface elevation model exists but not is referenced by DCDB
7	Z-values are assigned on cadastral corners
8	Ground surface elevation model is carried within the DCDB (or is strongly connected)
10	Digital twin of the jurisdiction exists, including ground surface elevations
SECTION 6. - TEMPORAL ISSUES	
6a	**Real-world history**
4	Time-limited spatial units are defined, but actual limits are not being recorded within Cadastre/LAS
6	Time-limited spatial units exist and temporal limits are defined within Cadastre/LAS
8	Moving boundaries are defined in X/Y/Z/time
10	Full digital history of boundary changes is supported (including subdivisions)
6b	**Legality of title**
0	A full historic search of titles is needed going back to the big bang!
5	A limited historic search of dealings shall be carried out
10	The registry of titles is current, and the single current title is definitive
6c	**History of database**

[1] Note that the respective question was not included in the first edition of the Questionnaire - 2010
[2] Note that the respective question was included first time in the 4th edition of the Questionnaire - 2022

0	The database(s) are point of time only (as up-to-date as possible)
2	Snapshots are taken at regular intervals
6	1D time – keeping reverse or forward deltas to track database changes
7	Some spatial units have 2 dimensions of time
8	Keeping a history of the database representation (The Versioned Object paradigm in LADM)[3]
10	Keeping real-world history as well as database representation history (The 2D time paradigm in LADM) [4]
SECTION 7. - RIGHTS, RESTRICTIONS AND RESPONSIBILITIES (RRRs)	
0	RRR information not available to Land Administration jurisdiction
4	Some distinctions in 3D RRRs compared to 2D
6	Same definition of 2D and 3D RRRs (and temporal if permitted) exist
10	RRRs are defined in form equivalent to LADM (or STDM)
SECTION 8. THE CADASTRAL DATABASE (Digital Cadastral Database - DCDB)	
0	No digital storage of Cadastral data exists
1	Graphics (in 2D) in a CAD / Graphics software, with the respective "attributes" stored in a textural database
2	The 2D graphics exist in a continuous (non-paged) storage scheme
4	The graphics and the attributes are stored within the same database & schema
5	Footprints of 3D parcels are stored in 2D, with an attribute indicating 3D
6	The 3D spatial units are stored in a separate repository
8	Link between the 3D and the 2D DCDBs (bi-directional link) exists
9	A single repository containing both 2D and 3D parcels with their full boundaries and attributes exists
10	A single repository, in LADM-compatible form, containing both 2D and 3D parcels with their full boundaries and attributes exists
SECTION 9 - PLANS OF SURVEY (INCLUDING FIELD SKETCHES)	
9a	**Definition and format**
0	No plans of survey are registered
2	There is a registered plan of survey to define all 2D spatial units (one plan can define many spatial units)
4	There is a registered plan of survey to define all 2D and 3D spatial units
6	For a 3D spatial unit, the plan contains enough information to completely define the boundaries (for all types of spatial units, but this may involve a reference to the actual building walls)
8	There exist spatial units for which the definition of the boundaries is complete without reference to a building walls or other objects
10	LADM-compatible format of survey information able to define the boundaries definitively exists
9b	**Connection between survey plans and DCDB**
0	No connection – both are maintained separately

[3] The concept is explained in Thompson et al. (2021)
[4] The concept is explained in Thompson et al. (2021)

5	DCDB contains extracted data from the survey plans, but the survey plan information is final in defining cadastral boundaries.
7	There is an automatic process to extract data from survey plans into the DCDB, but DCDB is not definitive.
10	There is automatic cross data flow between survey plans and DCDB and information in both is guaranteed.
SECTION 10 - DISSEMINATION OF 3D LAND ADMINISTRATION INFORMATION	
0	Cadastral maps are on paper form
1	Cadastral data available "in house" using network connections.
2	Spatial searches are allowed
3	Relevant software/hardware extend the availability of information dissemination
4	Multi-key access is provided (parcel identifier, house address, and other jurisdiction-specific keys)
5	Footprints of 3D parcels are depicted as 2D objects with colour or shading to indicate 3D or a 3D diagram is available through the 2D enquiry
6	The 3D spatial units are accessible to users with special software
7	3D spatial units are depicted on the 2D cadastral searches (the user doesn't need to know if a spatial unit is 2D or 3D to search for it)
10	Both the 2D and 3D spatial units are depicted on the one query mechanism.

For Section 11 – Statistic Information, no scoring is provided, but the aspects that were taken into account for the assessment and are provided through this section are:

- The number of 2D spatial units
- The number of 3D spatial units
- The population of the country/ jurisdiction
- The total surface area of the country/ jurisdiction

As presented in the Table, the rating scale ranges from 0 to 10, with 10 representing the most efficient status of a 3D LAS given the topic of the specific section, while 0 illustrates the less developed/ mature 3D LAS within this concept. Not all the scoring intervals at the various sections are the same, as this depends on the details that can be identified per topic that affect the scoring. For instance, in Section 8 regarding the DCDB, there are multiple scoring options provided, as the respective systems may significantly differentiate depending on the technical characteristics that are described at this rating scale, while for Section 7 – RRRs, less options are provided, as the alternatives can be grouped.

This assessment rubric is an initial approach to quantify the responses of the questionnaires and be able to monitor the progress of the countries that participate. Given the fact that this is developed and presented for the first time, there are some limitations that need to be addressed, specifically:

- Some questions have been changed over the years,
- Not all the responders started in the first year of the questionnaire,

- Not all the responders participate every four years at the questionnaire,
- The responders' interpretation of the questions varied from country to country according to their familiarization with the questionnaire, the terminology, their level of expertise and their wide knowledge of all the aspects that are asked within the questionnaire,
- The responders' interpretation of the questions from the same country may vary from each edition of the questionnaire, as not always the same participants respond to the questions, while at the most recent questionnaire, more participants were requested to join, aiming to involve people from both governmental organizations responsible for LA, as well as academia,
- The interpretation of the answers during the analysis varied between countries/ jurisdictions that the team analyzing them are already familiar with and can extract further info from what is answered. While, sometimes, the responses are not very clear and perhaps their interpretation from the team is not in line with the original response.
- Some of the rankings are not a simple linear score and the rankings may sometimes cross over.

3.2 Evaluation of countries using the assessment rubric for the FIG Questionnaire

Given this assessment rubric, a ranking has now been calculated for eight (8) countries over the past 4 questionnaires, spanning in total 16 years. The results are presented below, while the scores of each country in the different categories are visualised in diagrams to be able to compare the results of one country with previous questionnaires. The results from Queensland are presented in Figure 2 and it can be seen that the highest score ('10') refers to Section 6b (Title Legality), while Sections 4 (Coordinates) and 5 (Height) reach the lowest score ('2') for all the years of the questionnaires. Note that in the diagram of Figure 2 just the lines would result in overlapping lines in case no change over the years. Assuming that a county improves over the years it was decided to do a colour fill starting with the latest questionnaire (2022), first followed by the older ones drawing on top of this. In this manner it can be observed what progress was made over the years.

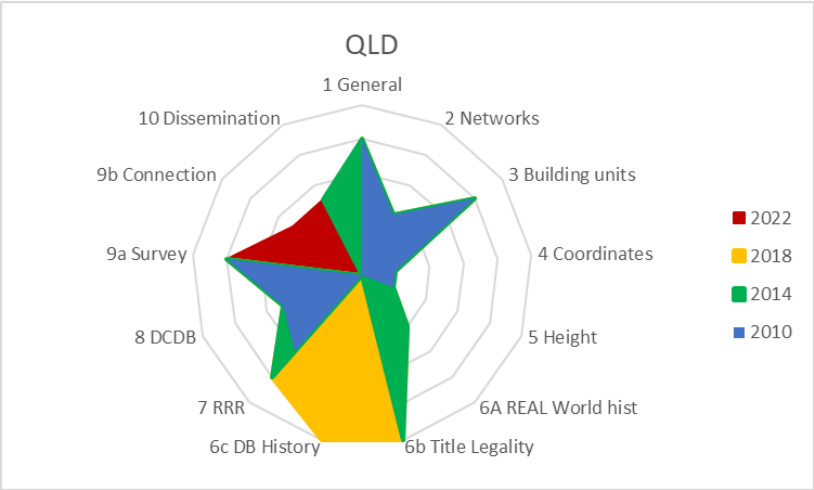


Figure 2. Queensland's (QLD) scoring in the various sections of the questionnaires, over the years.

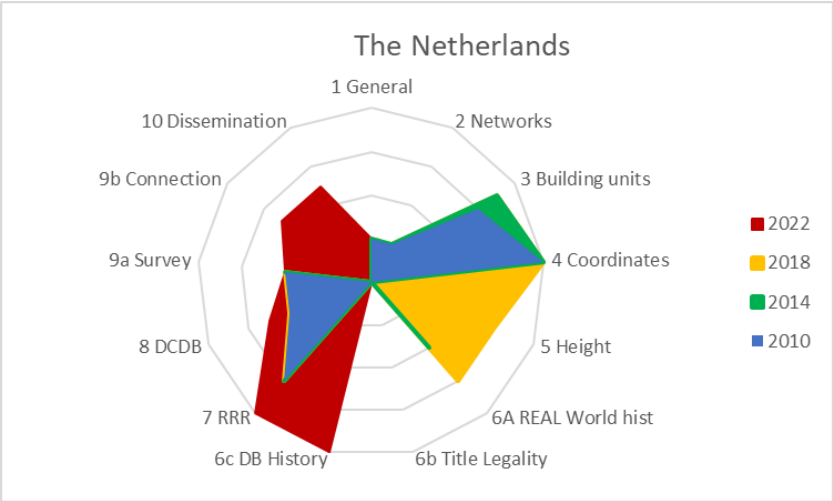


Figure 3. The Netherlands scoring in the various sections of the questionnaires, over the years.

The results from the scoring of the Netherlands for each of the sections of the questionnaire are presented in Figure 3. A spike is created for Section 6b (Title Legality) due to the fact that the scoring was '0' for the last two versions of the questionnaire that this section was completed. This makes sense as there are no titles in The Netherlands. For Section 7 (RRR) the differences on the score between the first 3 editions of the questionnaire ('6') with the higher score ('8') reached in the last questionnaire are depicted clearly in the diagram. Finally, for both countries, the Section 9b (Connection between survey plans and DCDB) is only answered in 2022 questionnaire, as it was introduced at this last edition.

What is more, for each one of the countries, a score has been given for all the sections based on the ranking scale of the rubric and the Manhattan distance is calculated. Moreover, the average of the scores is calculated. Both factors are computed for 2010, 2014, 2018 and 2022. The results are presented in the diagram depicted in Figure 4.

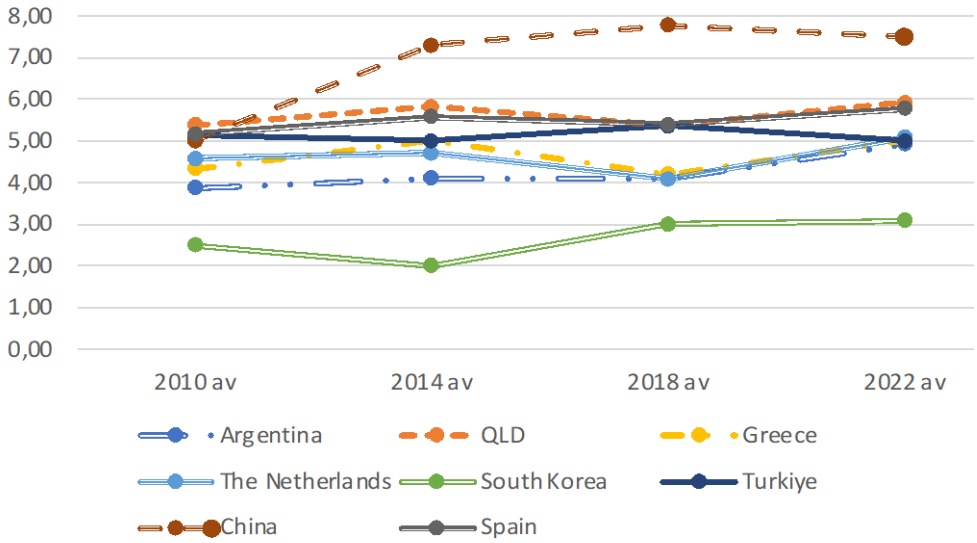


Figure 4. Total score computed for 9 countries using the rubric assessment for their responses at the four questionnaires, 2010-2022.

4. DISCUSSION AND FUTURE WORK

This paper provides follow-up of the four (4) earlier analysis papers on the FIG 3D Cadastres / Land Administration questionnaires, providing an overall idea and reflection on their advancement till now. Focus is given on the last FIG questionnaire 2022-2026 with respect to the LADM-related topics and the future trends and priorities of the countries for the coming four years, based on the initial analysis carried out by Kalogianni et al. (2023).

What is more, an assessment rubric is developed, providing a scoring of the responses in the various sections of the four (4) questionnaires. This is an initial approach to quantify the responses of the questionnaires and be able to monitor the progress of the countries that participate. Given the fact that this is developed and presented for the first time, there are some limitations that have been addressed. The evaluation is executed for eight (8) countries, leading to a score for each one of those. Given the limitations of the method, it is important to notice that the resulted ranking is based on the specific criteria developed in the paper and the responses provided by the participants and is not an official evaluation of the current LAS of the respective country.

The resulting ranking could be inspiring for countries to make more progress with regards to paying more attention or searching more the responses provided in the questionnaires (i.e. involving more experts if needed, etc.), as well as influencing the progress at national level with respect to the advances in the field of 3D LAS (if possible). What is more, this assessment rubric will initiate discussions regarding the clarity of the questions, their interpretation, the potential need to further update the questionnaire, as well as the current developments of the various aspects of 3D LAS per country.

As several new countries participated in the last edition of the questionnaire, while most of those that have participated in the previous editions still have the interest and contribute to this activity, it can be concluded that the interest on 3D Land Administration Systems worldwide is further growing and that the assessment may challenge more to participate.

The main future work directions are:

- Inform and align with countries/jurisdictions that are considering adopting LADM till 2026 or developing and LADM-based country profile (as responded in the last questionnaire) about the new developments in the context of LADM revision. It is a great opportunity as the timeline of these actions will run in parallel, given the fact that by the end of 2025 it is expected that the five first parts of LADM Edition II will be published as ISO standards.
- Work towards improving the limitations of the rubric assessment, also through consultation and open discussion with the countries that participate in this activity.
- Complete the scoring for the 19 countries/ jurisdictions that have participated in all 4 questionnaires till now, to have a more complete ranking.
- Update the next edition of the questionnaire, including the (improved) assessment rubric and request from the countries to do a self-assessment/scoring. Then, a cross-

check can be performed between the raking of the countries and the ranking of the analysis team, trying to eliminate the limitation of wrong interpretation.

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Evolution of UML application schemes in the Polish cadastral system in the context of legal changes

Jarosław BYDŁOSZ, Poland

Key words: 3D cadastre, 3D land administration, UML, Polish cadastral model

SUMMARY

After the Second World War, the Polish authorities were faced with the task of creating a land and building cadastre for a country whose territories had previously been covered by different legal systems. This task began with the issuing of relevant legal acts and regulations. They were all in textual form. Graphical notation appeared in Polish legal regulations in 2001 as an OMT diagram showing the main relationships between cadastral objects. This diagram is too general to construct a cadastral database on its basis. In 2013, a UML application schema describing the mutual relationships between cadastral objects appeared for the first time in the cadastral regulations. On the basis of the schema and detailed definitions of individual classes, it was possible to build a cadastral database. Since then, UML application schemes of the cadastre model have been included in Polish legal regulations. After 2010, many studies were conducted in Poland to develop the cadastre model, primarily proposing the introduction of 3D cadastre objects. These studies have not been significantly used in the preparation of new legal regulations. Since 2012, the subject has been running through the Polish parliament, considered as the issue of stratified ownership. Work on this topic has intensified since 2021 and is being conducted under the auspices of the De Republica Institute. At the time of writing this article, it had not been completed with the enactment of a new piece of legislation.

Evolution of UML application schemes in the Polish cadastral system in the context of legal changes

Jarosław BYDŁOSZ, Poland

1. INTRODUCTION

The Polish land administration system changed significantly after World War II. Some territories were lost, mostly to the Soviet Union, and some belonging earlier to Germany were gained. The very difficult issue of organising land administration (cadastre and land registry) of the whole territory, being earlier the subject of different regulations, became a great challenge. The Polish cadastral system after 1945 began to be shaped by various regulations, starting with the decree on land and building cadastres (Decree, 1947) that ordered the introduction of homogenous cadastre on the whole territory of Poland. Subsequently, the regulation on the procedure for establishing and maintaining a land and building cadastre (Regulation, 1950) was issued. New assumptions for the land cadastre institution in Poland were finally developed in the 1955 decree on land and building cadastre (Decree, 1955) and in the implementing regulations. Subsequently, the main regulations that have profoundly influenced Polish cadastre were ordinance on land cadastre from 1969 (Ordinance, 1969), law on geodesy and cartography (Act, 1989), and regulation on land and building cadastre from 1996 (Regulation, 1996). All this legislation, which consisted of both legal acts enacted by parliament and implementing regulations, was in textual form only. More details on the history of the Polish cadastre can be found in Mika (2010).

2. CONCEPTUAL MODELLING IN POLISH CADASTRAL REGULATIONS

Following technological development, cadastral systems became computer based. In the beginning, it concerned only the descriptive (textual) part. Later along with the development of graphical interfaces and spatial database solutions, the division of the cadastral system into descriptive and graphical parts (accordingly textual data and maps) started to disappear. Following this, most cadastral systems are becoming one model, like in “Cadastre 2014” vision (Kaufmann and Steudler, 1998), with all official papers and maps being not separate documents but reports obtained from the cadastral database.

2.1 OMT notation

The first legal act concerning cadastres that included some graphical schema was the regulation on land and building cadastres from 2001 (Regulation, 2001). The diagram of the main relationships between objects in the cadastre was defined in the form of the OMT (UML predecessor) notation. As this diagram was very general, it has illustrative rather than obliging significance. It has not neither the sufficient level of detail nor the attributes of cadastral objects were defined to make the reference model for Polish cadastre. The OMT diagram is presented in Figure 1. The translation of Polish cadastral system main class names into English (prefixes excluded) is presented in Appendix A.

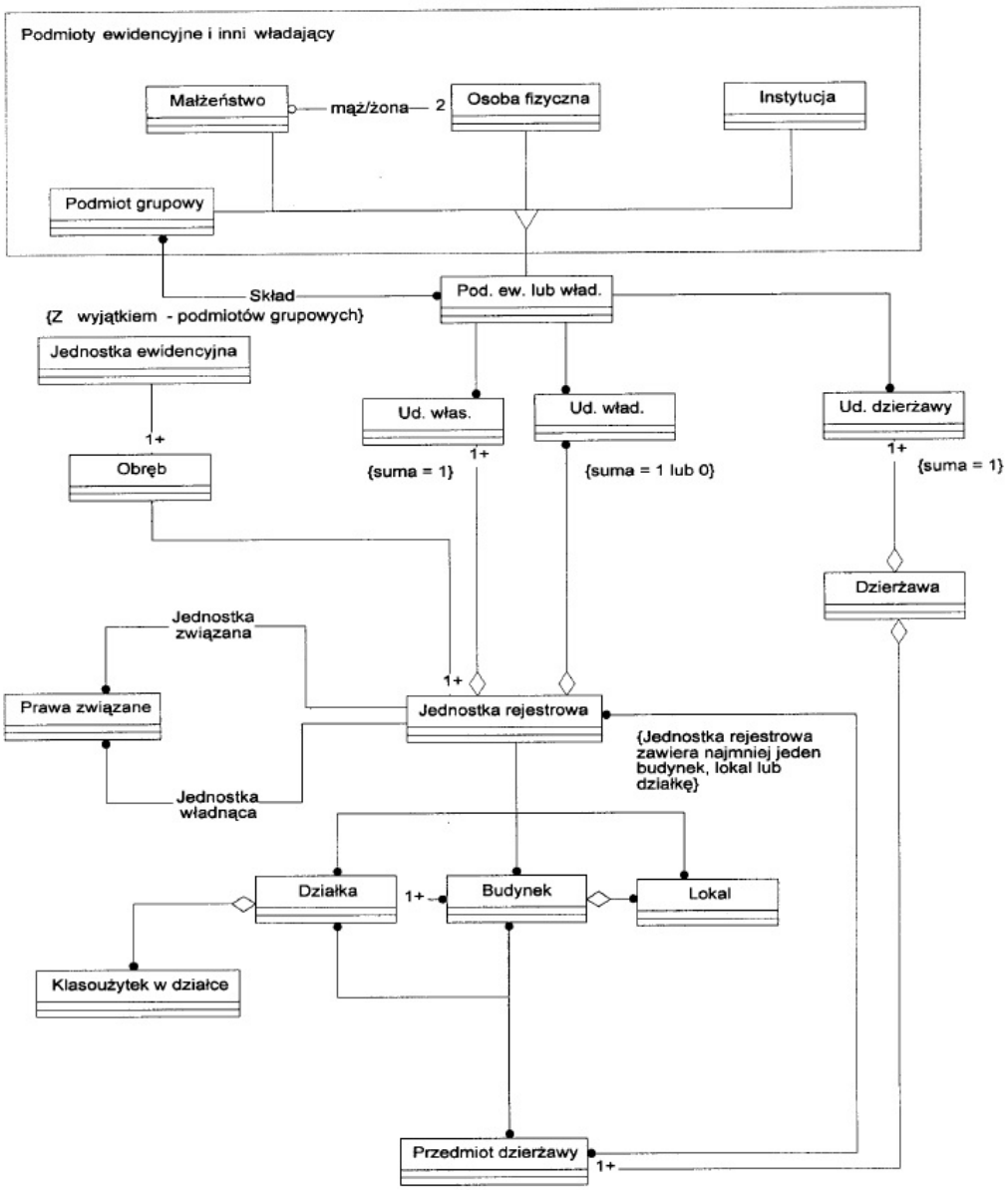


Figure 1. Schema of the main relationships between cadastral objects in OMT notation (Regulation, 2001)

2.2 UML notation in Polish cadastral regulations

2.2.1 Introduction

The Unified Modelling Language (UML) has been evolving since the second half of the nineties. In August 1997 UML version 1.1 was submitted to the Object Management Group (OMG) and accepted as a standard in November 1997. Since then, it has been developed by the Open Geospatial Consortium (OGS) In 2005, UML was published by the International Organization for Standardization (ISO) as an approved standard (Wikipedia, 2023) and has been periodically revised. According to a search on the ISO website, 83 standards already published or under development refer to the Unified Modelling Language (ISO, 2023). If we mean cadastral or land administration issues two regulations that apply UML seem

particularly important – INSPIRE directive and ISO 19152 'Geographic Information – Land Administration Domain Model' standard.

The INSPIRE directive, which entered into force in May 2007, is a legal act whose purpose is to establish the infrastructure for spatial information in Europe to support community environmental policies (Directive, 2007). The Directive addresses 34 spatial data themes needed for environmental applications, with key components specified through technical implementing rules. Unified Modelling Language notation is widely used in data specifications concerning particular spatial data themes e.g. Data Specification on Cadastral Parcels (INSPIRE, 2014) or Data Specification on Buildings (INSPIRE, 2013).

The ISO 19152 "Land Administration Domain Model (LADM)" was published on the 1st of December 2012 (ISO, 2012). The Land Administration Domain Model is a descriptive standard. It provides a reference model, which is supposed to serve two targets. One is providing an extensive basis for the development and refinement of efficient and effective land administration systems based on model driven architecture. The other is to enable the involved parties, both within one country and between different countries to communicate. The Land Administration Domain Model is a conceptual schema written with the Unified Modelling Language (UML) notation. It is performed according to the ISO 19100 series standard methodology.

Till now, the Land Administration Domain Model has been used in many studies concerning developing cadastral profiles for various countries (Kalogianni et al., 2021). Most of the standards are becoming outdated with time, so it is a general rule that every five years the standard should be revised and modernised if there is such a need. After five years after publishing ISO 19152, the idea of modernising the standard appeared and it was decided to start work on the LADM second edition. LADM edition II was proposed to be developed as multipart (coherent packages with every part in separate standard):

- Part 1 – Generic Conceptual Model
- Part 2 – Land Registration
- Part 3 – Marine Georegulation
- Part 4 – Valuation Information
- Part 5 – Spatial Plan Information
- Part 6 – Implementation Aspects.

The details of the LADM edition II developments are described in (Lemmen et al., 2023). According to the International Organization for Standardization (ISO, 2012), the first five parts are under development.

2.2.2 Regulation on land and building cadastre from 2013

The UML scheme appeared for the first time in Polish cadastral legislation in the Regulation of the Ministry of Administration and Digitization from 29th November 2013 (Regulation, 2013). The regulation from 2013 was not directly based on ISO 19152 'Land Administration Domain Model', for inter alia, they were both developed in a similar period. However, it seems that the regulation generally meets the LADM criteria (Bydłosz, 2012).
The land and building cadastre database UML application schema and detailed cadastre object catalogue are part of the regulation. The UML cadastral model included in the regulation

consisted of 16 diagrams and was grouped in eight thematic packages, which consisted of 71 classes making up the Polish cadastral model. More details concerning the Polish cadastral model from 2013 can be found in (Bydłosz, 2015). The diagram ParcelContourOfSoilQualityValuationInParcel is presented in Fig. 2 and the translation of names of main classes into English is listed in Appendix A.

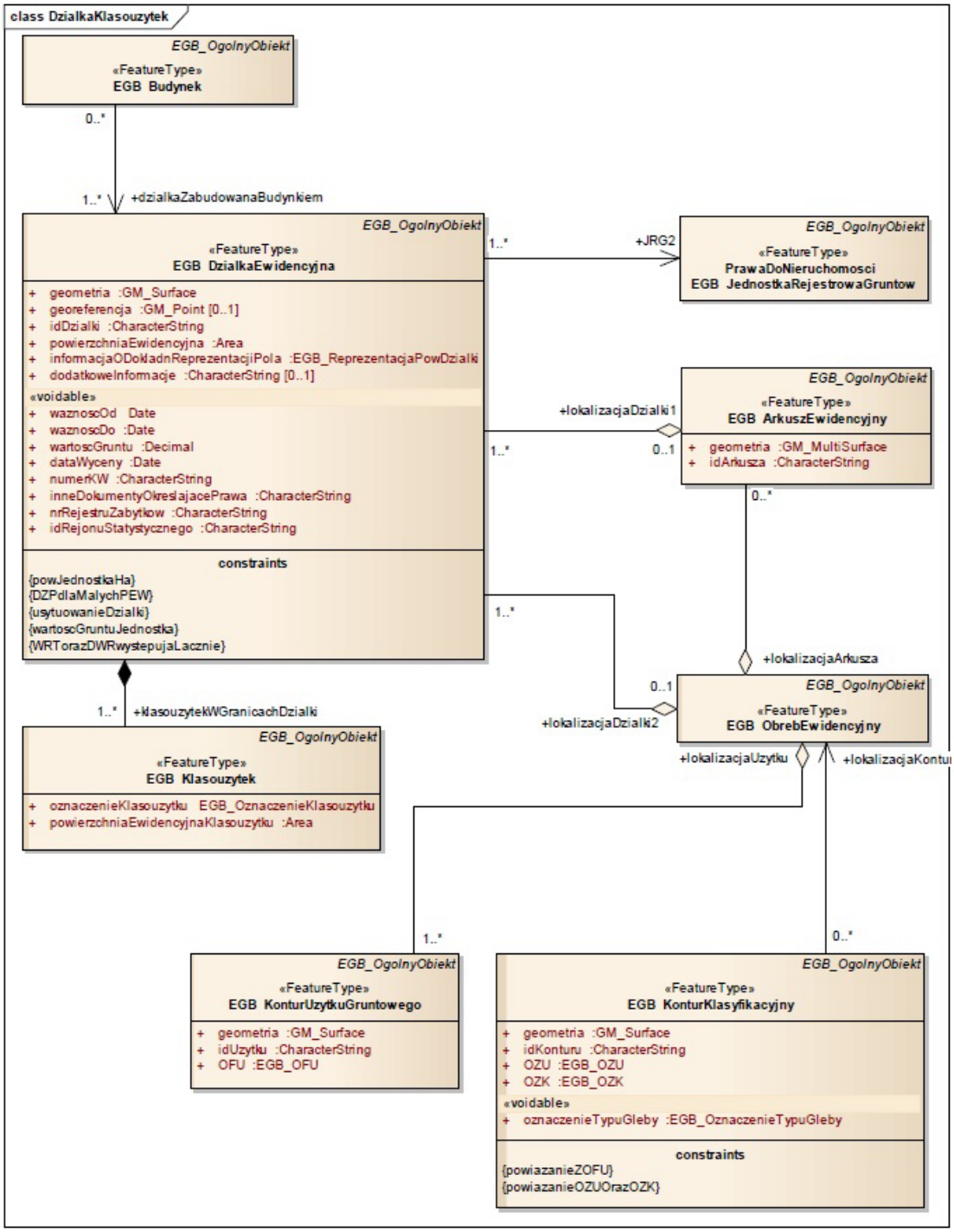


Figure 2. Diagram 'ParcelContourOfSoilQualityValuationInParcel' (Regulation, 2013)

2.2.3 Subsequent regulations on the land and building cadastre

Since then, the regulations on land and building cadastre have changed several times (Regulation, 2015), (Announcement, 2019) with corresponding changes in the UML cadastral model. However, a significant modification took place in 2021 when a new regulation on land and building cadastre was published (Regulation, 2021). The earlier UML schema defining the Polish cadastral model was substituted with the new one. In 2023, some small changes to the text of the regulation and the UML model were made (Regulation, 2023). Both UML models – the one from 2021 and the binding one from 2023 are very different from the previous ones. This UML schema describing the Polish cadastral model consists of 11 diagrams. The are:

- General object,
- Inheritance,
- Object data,
- Party data,
- Register units and parties group,
- Shares,
- Party address,
- Property address,
- Boundary point,
- Legal basis,
- Graphical presentation.

The diagrams include 44 objects classes defining the Polish cadastral model (starting with prefix 'EGB_') and two additional classes from the Infrastructure of Spatial Information in Poland – 'GraphicPresentation' and 'Label'. The UML classes describing the Polish cadastral model include:

- 25 'FeatureType' classes,
- 18 'Enumeration' classes,
- 1 'Datatype class'.

Three FeatureType classes appear with stereotype 'Union', as well. The diagram 'LegalBasis' is shown in Fig. 3 and the translation of names of main classes into English is presented in Appendix A.



Figure 3. Diagram 'LegalBasis" (Regulation, 2023)

3. WORKS ON EXTENDING POLISH CADASTRAL MODEL

3.1 Scientific research

The ideas about a 3D cadastre have gained widespread popularity in Poland, since completing and publishing the questionnaire on 3D cadastre within the activities of the FIG Joint Commission 3 and 7 Working Group on 3D Cadastres (Questionnaire, 2010). One of the results was the start of research studies concerning 3D cadastre issues in various academic centres in Poland. They were either based on practical examples, are theoretical models, or are a combination of both. A short review of cadastral works in Poland that include UML models of cadastre is presented below.

A model of a 3D+time cadastre is proposed by Siejka et al., (2014). The transition method from a 2D cadastre to a 3D cadastre (including the time factor) is described in this section. The UML simplified models for a real property register, a land and building cadastre, the spatial registration of utility infrastructure, and a 3D+time cadastre are also presented in this paper.

The application of CityGML for 3D representations of buildings is described by (Góźdź et al., 2014). Based on practical examples obtained from airborne laser scanning and applying CityGML, 3D representations of building legal spaces are proposed. The cadastral concept based on the 3D-LADM country profile development for Poland was proposed by Góźdź and Pachelski (2014). Land Administration Domain Model packages are applied, and new 3D objects such as PL_3DParcel, PL_RestrictedParcel, and PL_UnrestrictedParcel are implemented.

The expansion of the cadastral system functionality for the new 3D objects was proposed in Bydłosz et al. (2013) and Bydłosz (2014). The three-dimensional parcels are represented by the EGB_CadastralParcel3D and EGB_BuildingLegalSpace3D classes. According to this model, 3D parcels can be situated above the ground, under the ground, or a combination of both. The introduction of 3D cadastre classes into the Polish cadastral model is described in Bydłosz (2016). The classes representing the proposed 3D cadastral objects are implemented in the Polish cadastral model defined earlier in the legal regulations (Regulation, 2001). The model comprises original cadastral classes (Regulation, 2013) as well as 3D cadastral objects added in earlier research works (Bydłosz et al. (2013) and (Bydłosz, 2014). The introduction of spatial planning model classes into the proposed Polish cadastral model is described in (Bydłosz et al., 2018). The trial of modelling historical objects in the proposed 3D cadastre is described in (Bieda et al., 2020). The new model for the Polish cadastre based on (Regulation, 2015) and earlier works (Bydłosz, 2016) is presented in (Bydłosz and Bieda, 2020). A wider overview of cadastral works in Poland is presented in (Bydłosz, 2022).

3.2 Work on multilayer ownership in parliament

The term ‘3D cadastre’ is widely known among professionals such as surveyors, architects, and urban planners. Term ‘3D land administration’ is not very popular in Poland because of difficulty with its direct translation into the Polish language. Moreover, it seems that the Polish legislators understand this problem in a different way - as a multilayer (stratified) ownership issue, with the emphasis not on ownership registration but on its definition in 3D. The starting point for works seem to be the Civil Code (1964).

The issue of stratified ownership appeared in Polish parliament for the first time in the parliament interpellation submitted on 26th of September 2012 by John Abraham Godson, MP (Interpellation, 2012). It was stated in the interpellation content that stratified ownership solutions are popular in many countries, and their lack in Poland seriously restricts development possibilities in intensively urbanised areas.

In response to this inquiry, the Ministry of Transport, Construction and Maritime Affairs explained that proper works had taken place in the ministry since 2009 and the draft proposal suggested the introduction of a new type of property, i.e., building structures situated above or

below the surface of the property, which, under the proposed Act, would be able to constitute an object of ownership separate from the land (Response, 2012).

The raising of the topic, both at that time and in subsequent parliamentary terms, was largely due to problems occurring in connexion with the planning or preparation of developments primarily on land held in perpetual usufruct, which often occurs in Polish Rail (PKP) companies and severely restricts or hinders the management of space, often in areas that are attractive for development.

For the next several years, various works were occurring in the proper ministries, but they did not result in the issuance of corresponding legal acts. Then, as part of the work of the Sejm (Polish Parliament Lower House) 8th term, in 2018 the "Parliamentary Team on Strata Property Law" was established and held one substantive meeting before the end of its term. The present parliament has also taken up the issue - the 'Parliamentary Team for the introduction of stratified ownership in Poland' was set up in 2021 (Parliamentary Team, 2023). It inspired works on stratified ownership that started and continued under the auspices of 'De Republica Institute'. Finally, at the Parliament Team session on August 29, 2023, the assumption to the 'Law on stratified development' prepared in 'De Republica Institute' was to be presented. Till this point, no proposed solutions have been officially published.

4. DISCUSSION AND CONCLUSIONS

As previously described, UML was introduced into Polish cadastre legislation for the first time in 2013 as the 'UML application schema for land and building cadastre data'. Between 2015 and 2019, the UML schemes underwent minor changes to adapt to amendments of the cadastre legislation. In 2021, there was a major overhaul of the UML application schema of the Polish cadastre (with minor changes in 2023), where both the number of diagrams and classes were reduced.

It can be argued that the introduction of UML schemes into Polish legislation has been beneficial because it has introduced a large measure of standardisation into the construction of databases managing cadastral systems. However, UML schemes reflect legal regulations - primarily executive regulations, and their evolution is preceded by changes in the legal state. Polish legislators are practically not familiar with the concepts of '3D cadastre' and '3D land administration'. On the other hand, the issue of stratified ownership has been around since 2012. Intensive work on the law of stratified ownership has been conducted since 2021, but it is difficult to predict whether it will be completed before the parliamentary elections, which are due to be held on the 15thOctober, 2023.

After 2010, a lot of scientific work was conducted using the UML model of the Polish cadastre. These were mainly proposals for the introduction of various objects of the future 3D cadastre into Polish legislation. However, to date, the use of these works in legal or implementation solutions is negligible.

In terms of official acts, until the work on the stratified property law (2021) was undertaken, there were mostly minor changes to the legislation and the UML schemas. There were mainly modifications of the implementing legislation - successive regulations on the land and building cadastre.

At the moment, it seems that further work on building a '3D cadastre' or '3D land administration' (with simultaneous development of UML schemes) may proceed after the possible enactment of the stratified ownership law and its implementing acts. Until then, the implementation of any solutions resulting from scientific work in Polish cadastre legislation seems unlikely, as well.

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BIOGRAPHICAL NOTES

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APPENDIX A

Translation of Polish cadastral system main classes names into English language.

Polish model original class name	**Name in the Poland's profile**
BlokBudynku	BlockOfBuilding
Budynek	Building
Dokument	LegalDocument
DzialkaEwidencyjna	CadastralParcel
Dzierzawa	Lease
Instytucja	Institution
JednostkaEwidencyjna	CadastralComplex
JednostkaRejestrowa	RegisterUnit
JednostkaRejestrowaBudynkow	RegisterUnitOfBuildings
JednostkaRejestrowaGruntow	RegisterUnitOfLand
JednostkaRejestrowaLokali	RegisterUnitOfPremises
Klasouzytek	ContourOfSoilQualityValuationInParcel
KonturKlasyfikacyjny	ContourOfSoilQualityValuation
KonturUzytkuGruntowego	ContourOfLandUse
LokalSamodzielny	Premises (Apartment)
Malzenstwo	Marriage
ObrebEwidencyjny	CadastralSection
OgolnyObiekt	GeneralObject
OperatTechniczny	TechnicalDocumentation
OsobaFizyczna	NaturalPerson
Podmiot	Party
PodmiotGrupowy	GroupParty
PunktGraniczny	BoundaryPoint
RodzajDokumentu	TypeOfDocument

RodzajPrawa	TypeOfRight
RodzajUprawnien	RightType
RodzajWladania	TypeOfHolding
UdzialWlasnosci (Ud. włas)	ShareOfOwnership
Zmiana	Change
ZrodloDanychZRD	SourceOfData

3D Land Administration System for Wilayah Sarawak based on LADM Edition II– Preliminary Works

Ainn ZAMZURI, Alias ABDUL RAHMAN, Muhammad Imzan HASSAN, Malaysia and Peter VAN OOSTEROM, Netherlands

Keywords: ISO 19152:2012 LADM, Land Administration, Country Profile, Registration System, 3D LAS

SUMMARY

The numerous country profiles developed in compliance with ISO 19152:2012 Land Administration Domain Model (LADM) in different jurisdictions worldwide reflect the standard's growing significance and acceptance. A country profile may outline the current situation in the land administration (LA) domain and adapt the existing land administration system (LAS) into the LADM concepts, or it may indicate the requirement or desired outcome for a possible future scenario in a specific country. Previous studies show that many countries, such as Brazil, China, Croatia, Netherlands, etc., have developed their country profiles based on LADM. In the meantime, the Malaysian LADM country profile also has been developed. However, it only applied to Peninsular Malaysia (Sabah and Wilayah Sarawak are omitted) since different LA is being practiced. Currently, the Wilayah Sarawak has an integrated organization, Department of Land and Survey Sarawak, applied in the LA domain where all the departments (e.g., Land Registry, Planning, Valuation, Title Registration, Survey and Cadastral Mapping, etc.) contribute the information accordingly in that system. The Sarawak country profile is based on LADM edition II (under development), and is the first country profile reported using all parts (of the new multi-parts LADM edition II), arriving at truly integrated LA. The experience may shall be used on input to the final version of LADM edition II. The new functionality modelled, such in the 3D representation, provide path to Sarawak future. It is the aim of this paper to describe the Wilayah Sarawak country profile development based on LADM Edition II. Relevant 2D and 3D spatial and non-spatial objects of LA, including Native Customary Rights (NCR) data, are the focused of the development of the Wilayah Sarawak LADM Country Profile classes. The country profile model is developed to establish a much broader system related to the land administration of the state.

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1. INTRODUCTION

Malaysia comprises two main land masses, Peninsular and East (Sarawak and Sabah) Malaysia (Hayward, 2021). Land governance in Malaysia is highly pluralistic. In the Peninsular, the majority of the Land Administration (LA) tasks are handled by at least two institutions, namely the Malaysia Department of Survey and Mapping (DSMM) and the Land Office (LO). The DSMM handles the spatial components, whereas LO manages the land registration. The spatial components deal with cadastral information, such as the boundaries of the land parcel. Meanwhile, land registration focuses on cadastral attribute information, such as the legal rights of the properties. However, both are pretty comfortable with 2D-related data but not 3D, as Zulkifli et al. (2015) and Hassan (2017) reported. The Federal Department of Surveying and Mapping (JUPEM) carries out cadastral surveying using eKadastar. In contrast, at the state level, the land office uses eTanah to manage and administrate land (Choon et al., 2015). LASIS is the information system in Sarawak for the land cadastre and administration system. At the same time, Sabah uses LaDess as a land submission system and SALIS as an information system (Abdullah et al., 2017).

During FIG Congress 2010, Hassan M. I. & Rahman A. (2010) proposed for an integrated 3D Cadastre Registration System for Malaysia where some classes (Persons, RegisterObject, RRR) in the initial version of LADM have been adopted, and several 3D components (registration of right-volume and 3D physical object) have been implemented into the data model. 3DParcel has been introduced (to hold 3D objects) as the new class for the data model where it bounds between 2D geometry and 3D information. In 2014, Zulkifli (2014) developed a Malaysia LADM Country Profile for land administration in Malaysia where the model is feasible for Peninsular Malaysia and can be extended for Wilayah Sarawak. Since Wilayah Sarawak has integrated land administration, this paper proposes a 3D LAS for the Sarawak based on LADM Edition II (using all new multi-parts)—more elaborations at the later stage of this paper.

2. MALAYSIA LADM COUNTRY PROFILE

The Malaysian LADM Country Profile is developed using User Requirement Analysis (URA) data from DSMM and the LO. As indicated by Zulkifli et al. (2015), the URA for this country profile is produced through workshops and meetings conducted by the cadastral group and

UTM (in collaboration with TU Delft). Several ideas were gathered and addressed (e.g., 3D lot, BAUnit, strata objects, 2D topology, intermediate points, spatial source, administrative source, level, abstract class, identifier, code list, constraint in share attribute, indexing, clustering, and implicit or explicit encoding of CRS and UoM). This country profile is extended in the form of spatial and administrative parts. The LADM model's inherited classes are indicated by an italicized class name in the upper right corner of the corresponding class.

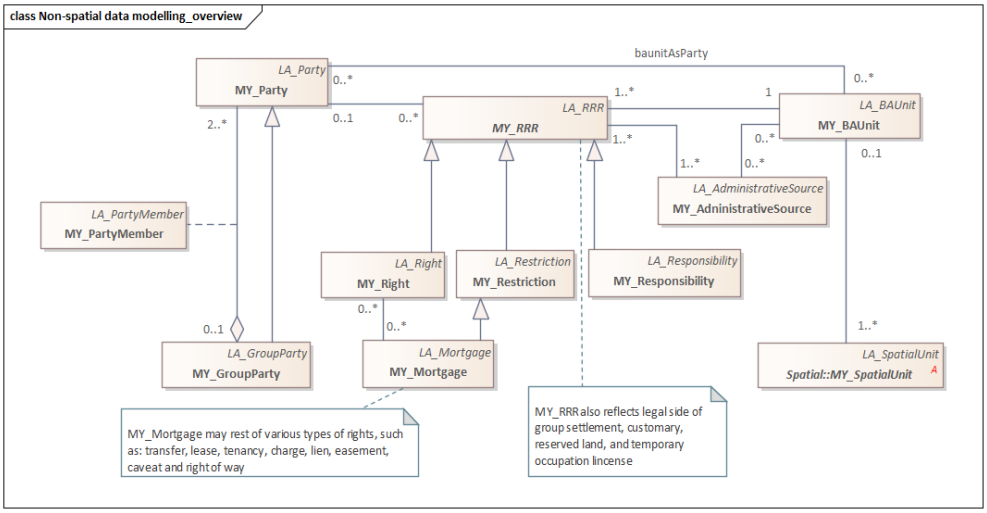


Figure 1: Overview of Malaysia LADM Country Profile (Non-Spatial Part) adopted from Zulkifli et al. (2015)

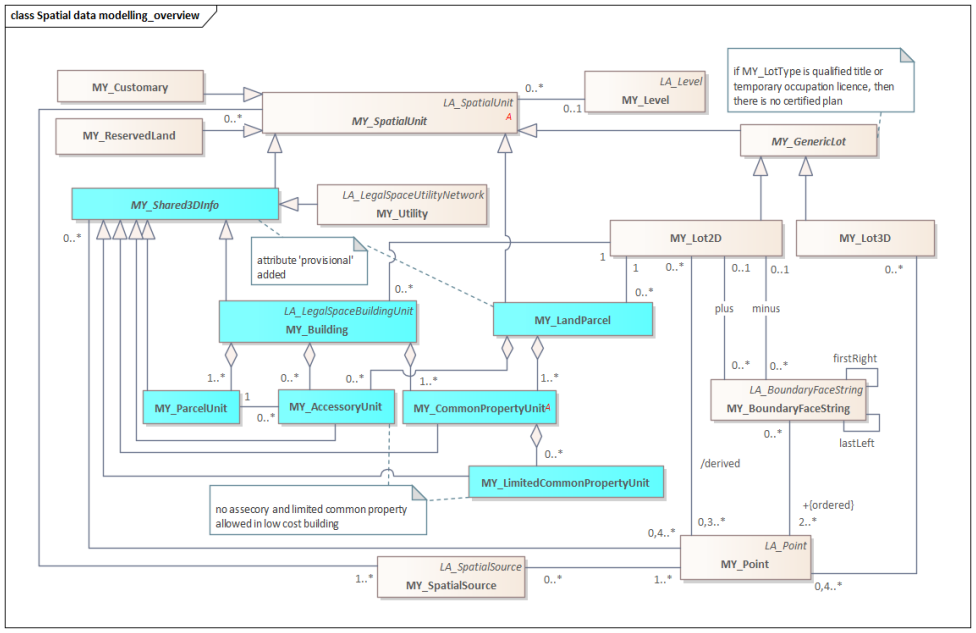


Figure 2: Overview of Malaysia LADM Country Profile (Spatial Part) adopted from Zulkifli et al. (2015)

Spatial units in Malaysia can be in 2D or 3D form. From that case, Zulkifli (2014) is introduced some abstract classes for LADM in Malaysia. The abstract classes, namely, MY_GenericLot, MY_Level, MY_SpatialUnit, MY_SpatialSource, and MY_Shared3DInfo. 'MY_' term is represent for Malaysia and used to define both administrative (see Figure 1) and spatial (see Figure 2) parts of the data model as a prefix. These abstract classes only support the modeling process and represent shared attributes.

Since LADM Country Profile for Peninsular Malaysia has been developed, thus it can be a good reference in developing country profile for Wilayah Sarawak. Any suitable classes and attributes from the Malaysia Country Profile can be adopted into Wilayah Sarawak profile. Moreover, Kalogianni et al. (2021) have presented a methodology for the development of country profiles, and this outline could offer an additional set of guidelines for the development process. Thus, investigation on current land administration in Sarawak is needed to develop a 3D LAS for the Sarawak. Further elaboration on current land administration for Wilayah Sarawak as described in Section 3.

3. PRELIMINARY WORKS ON 3D LAS FOR THE WILAYAH SARAWAK

This section elaborates the structure for Wilayah Sarawak Country Profile based on the suggested outlines from Kalogianni et al., (2021). The development of the data model is designed according to the structured characteristics as follows.

3.1 Profile scope

Sarawak has a land administration and registration system that is well-established and uniform, based on the Torrens principle as discussed by Osman S. & Kueh H. U. (2010). The administration records the fundamental aspects of parcels of land and their boundaries to provide a legal definition of a land parcel. Sarawak Land and Survey Department is responsible for surveying, land administration, planning and evaluation. They have developed an integrated land information system, known as LASIS (https://elasis.sarawak.gov.my/), to record land ownerships, land values, land use, and other related data for managing the land information. LASIS is an additional channel for the general public to interact with and provides several services such as land rental, land lease renewal, etc.

Land resource managers have full access to land and property information to understand the interdependencies between multiple services of land professionals. The procedure for formalizing and transferring land rights has been made simple through direct alienation of state land, the methodical adjudication and demarcation of customary rights under the land laws, and the adoption the Torrens Title System. The term "State land" refers to all land that lacks an issued document of title and any land that, following the issuance of a document of title, might have been or could be forfeited, surrendered, or reclaimed by the Government (Sarawak Land Code, 1958). This definition encompasses:

(a) The bed of any river, stream, lake or watercourse
(b) The foreshore and beds of the sea within the boundaries of Sarawak as extended by the Sarawak (Alteration of Boundaries) Order in council, 1954 [Vol. VI, p.1025]

Sarawak Land Code (SLC) outlines the rules and procedures for land tenure, land registration, land administration, land acquisition, and related matters. It defines the different types of land ownership, including Native Customary Right (NCR) land, which is of particular significance to indigenous communities in Sarawak. The code also governs the conversion of land for various purposes, such as agriculture, development, and conservation.

Given the diverse cultural and historical context of Sarawak, the land code addresses issues related to both native customary rights and modern land ownership practices. Over time, the land code has undergone amendments and revisions to adapt to changing circumstances and address evolving land-related concerns in the state.

3.2 Stakeholders' involvement

Currently, land administration and registration are managed by a single department namely, Land and Survey Sarawak where all the branches (Land, Survey, Valuation and Spatial Planning) are under one 'roof'. The Land and Survey Department is a leading agency in land management and land administration. Matters under its jurisdiction are land, planning, valuation, survey, and enforcement of the land laws under the land code. Details of responsibilities for each branch as described below.

3.2.1 Land Branch

The main function of this section is to process any application for land for development such as for commercial, industrial, residential, agricultural, recreational, office, institutional or any other purposes.

(a) Carry out survey works on all land in Sarawak and register them onto the Land Register unit.
(b) Confirm the boundaries of native's land and register for security of tenure.
(c) Identify the boundaries of state land.
(d) Replace Pre-Land Code titles such as various types of Occupation Tickets, Rubber Garden Certificates and Squatter's License

3.2.2 Survey Branch

This branch is responsible for processing, managing, storing, and maintaining spatial data acquired and survey related activities carried out in the state.

(a) Providing geodetic controls in the state.
(b) Carrying out aerial photography survey.
(c) Compiling and producing topographic, thematic and town maps of Sarawak.
(d) Sale of restricted and unrestricted maps of Sarawak, survey plans, aerial photographs and orthophotos.

(e) Overseeing cadastral survey works carried out by both Government Surveyors and Licensed Land Surveyors in the state and ensuring the standard of survey work is maintained and that survey practices are in accordance with the Survey Branch technical requirements and the Land Surveyors Ordinance, 2001.
(f) Storing and maintaining spatial data acquired by the Department.

3.2.3 Planning Branch

Planning branch is responsible for planning and controlling development in accordance with the principles of town and country planning. It also manages and monitors the implementation of Land and Survey Department development projects and give planning advice to the Government and the private sector.

(a) Monitor and process development applications that involve land conversion, amalgamation, and land subdivision (AVTC) / subdivision / amalgamation of land)
(b) Processing applications by government agencies
(c) Processing applications for construction of telecommunication towers
(d) Provide and produce various types of plans such as structure plans, local plan, service centre, kampung extension scheme, resettlement scheme, landscape plan and roading plans
(e) Transforming 2D proposed plan into a 3D virtual reality presentation for the State Planning Authority meeting

3.2.4 Valuation Branch

Valuation Branch is responsible for managing land acquisition in accordance with the Government Development Programs. Besides that, it is responsible for assessing promptly all fees due to the Government as well as to provide professional advice to Government Agencies.

(a) Carry out compulsory Land Acquisition
(b) Providing Assessment of Premium and Annual Rent
(c) Miscellaneous Valuation Services

3.3 Status of LAS

The main ethnic divisions in Wilayah Sarawak are comprised of Malay, Chinese and 'Dayaks' - the native peoples of Borneo (King et al., 2017). In Sarawak, *Iban* people represent 30% of the Dayaks (Ichikawa, 2007). The *Iban* communities acknowledge a unique bond with their ancestral lands and territories, as noted by Aiken and Leigh (2011). Nevertheless, conflicts emerge involving the communities, the government, and private market participants. The communities aim to safeguard their lands, while the private entities strive to advance extensive commercial logging and large-scale plantations, as highlighted by Cramb (2007).

The *Iban's* traditional land ownership system relies on *adat* (customary*)*, which encompasses NCR. NCR is the rights and priviledges that indigenous communities have over the lands and

resources they have traditionally used and occupied. These rights are often recognized under law or customary practices. In accordance with native beliefs, "clearing and cultivating untouched land bestows permanent rights upon the initial cultivator" (Bulan, 2008). The fundamental unit holding these rights is the household, while the "longhouse community" (see Figure 3 for longhouse in Sarawak) functions as the core land management entity within the community's borders. The *Iban's* system of governance and land tenure is structured around a community-centered approach, wherein individuals seldom exhibit free-riding tendencies. They collaborate to ensure the lasting well-being of the entire community. According to Land and Survey Department of Sarawak, the longhouses are not being mapped and registered because the longhouses can be built and demolished in anytime. Being a part of the longhouse community entitles individual households to possess general access rights to community land and resources, as observed by Aiken and Leigh (2011).



Figure 3: Example of longhouse in Sarawak [source:Malaysia-sarawak-longhouse-19 photography (2017)]

In Sarawak Land Code (SLC), Section 5 (2) appears to be crucial for native people since it integrates their cultural practices in the SLC where different methods through NCR can be acquired (see Figure 4), yet only under Interior Area Land (IAL) after obtaining a permit from a district officer.

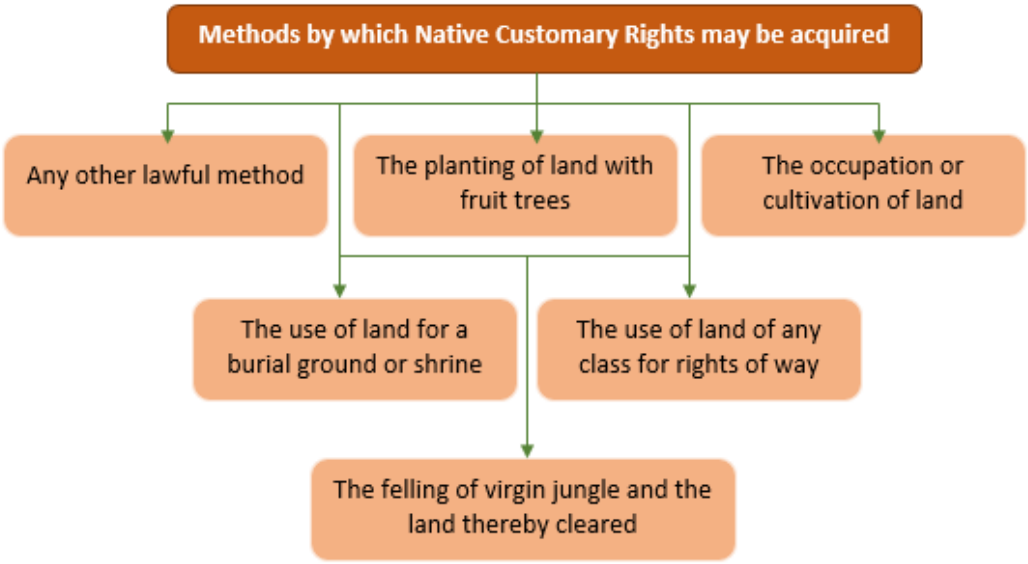


Figure 4: Methods acquired by NCR

The SLC does not fully acknowledge NCR. While the state only acknowledges farmland that was cultivated prior to January 1, 1958 as Native Customary Land (NCL). *Iban* people perceive their communal territories, village forest reserves (pulau galau), and farmland as part of their SCL territorial domain. "Pulau Galau" refers to "communal forest reserves" in the context of the indigenous communities, particularly the *Iban* people, in Sarawak, Malaysia. These are areas of land traditionally designated and preserved by these communities for various purposes, including cultural practices, resource management, and spiritual significance. "Pulau Galau" translates to "sacred forest" in the Iban language. These forest reserves are often considered crucial components of the traditional land management systems of indigenous groups. They are set aside to protect the environment, preserve biodiversity, and sustain the cultural practices and beliefs of the community. The concept of "Pulau Galau" reflects the deep connection between indigenous communities and their ancestral lands, highlighting their efforts to maintain a harmonious relationship with nature while preserving their cultural heritage.

In the light of this, the government regards any uncultivated land or virgin forests as state land, thus considering land under traditional forest-fallow practices as abandoned or undeveloped in the SLC, thereby belonging to the State.

3.4 Profile development stage

Sarawak Country Profile is developed by adopting ISO 19152 Land Administration Domain Model (LADM) edition II reflecting the current cadastral system in Sarawak Land Registry/Survey (only), not valuation and spatial planning (in detail). The current cadastral system was integrated into four departments: survey, land registry, valuation, and planning.

Hence, we attempt to develop a country profile that adaptable to all the departments. UML diagrams were created, where three core packages were applied with adaptation to local (Sarawak) needs. The modelling process is at conceptual level. In this data model, several code list values were introduced in WS_PartyType, WS_PartyRoleType, WS_TypeOfNativePeople, WS_TypeOfReservedLand, WS_TypeOfCustomaryLand, WS_TypeOFSpatialSource and etc. suit to the Sarawak cadastral system. The prefix 'WS_' is used to represents Wilayah Sarawak. All the classes were associated to suitable classes. Code lists were included in the data model.

3.4.1 Non-spatial Part (Party and Administrative Packages)

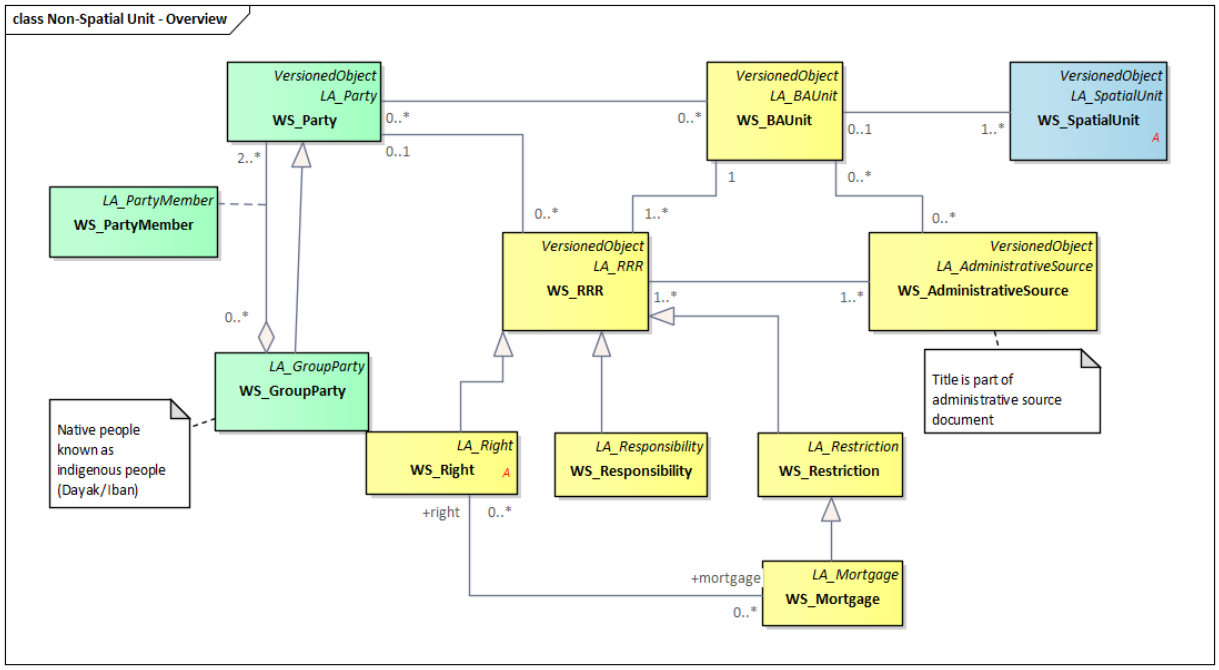


Figure 5: Overview of Non-Spatial Part of Wilayah Sarawak LADM Country Profile

Figure 5 illustrates the classes pertaining to the non-spatial unit of the Sarawak LADM Country Profile. The relationships between these classes were meticulously crafted based on their interconnections. Specifically, the WS_Party and WS_GroupParty classes were incorporated from the LADM framework. The WS_TypeOfNativePeople class is employed to denote the indigenous populations in Sarawak, including groups like *Dayak* and *Iban*. Meanwhile, WS_LandCategory is used to represent various land types found in Sarawak, and WS_TypeOfTitle is integrated as part of the administrative source documents.

WS_AdministrativeSource is associated with both WS_RRR and WS_BAUnit. In the LADM Malaysian country profile, the spatial unit is denoted by suID, whereas sID is employed for

both spatial and administrative sources. Specifically, in the Malaysian country profile, suID is derived from the Unique Parcel Identifier (UPI). The sID for spatial sources corresponds to the certified plan number, while the sID for administrative sources represents the title number. This same convention is followed in Sarawak administration, where suID is utilized, also based on the UPI, but it does not include 'mukim' information. More detailed information regarding the non-spatial aspect can be found in Appendix A.

3.4.2 Spatial Part (Spatial Unit Package)

Figure 6 shows the spatial part of the country profile. WS_SarawakLandUseType, WS_TypeOfSpatialSource, WS_TypeOfParcelUnit and WS_TypeOfValuationUnit were added into the spatial unit package. WS_SpatialUnit is generalized by WS_LegalSpaceParcel to identify the type of land use of the spatial unit is. Then, WS_GenericLot was adopted from Malaysia Country Profile where this class only supporting the modelling process, representing shared attributes and structures.

One of the important foundations of LADM is the fact that all information in the system should originate from source documents and that the association to the source document is explicitly included. In case of spatial source documents (usually certified plans) there are links with spatial unit and point tables: WS_SpatialSource has association with WS_SpatialUnit and WS_Point. Details on the spatial part can be seen in Appendix B.

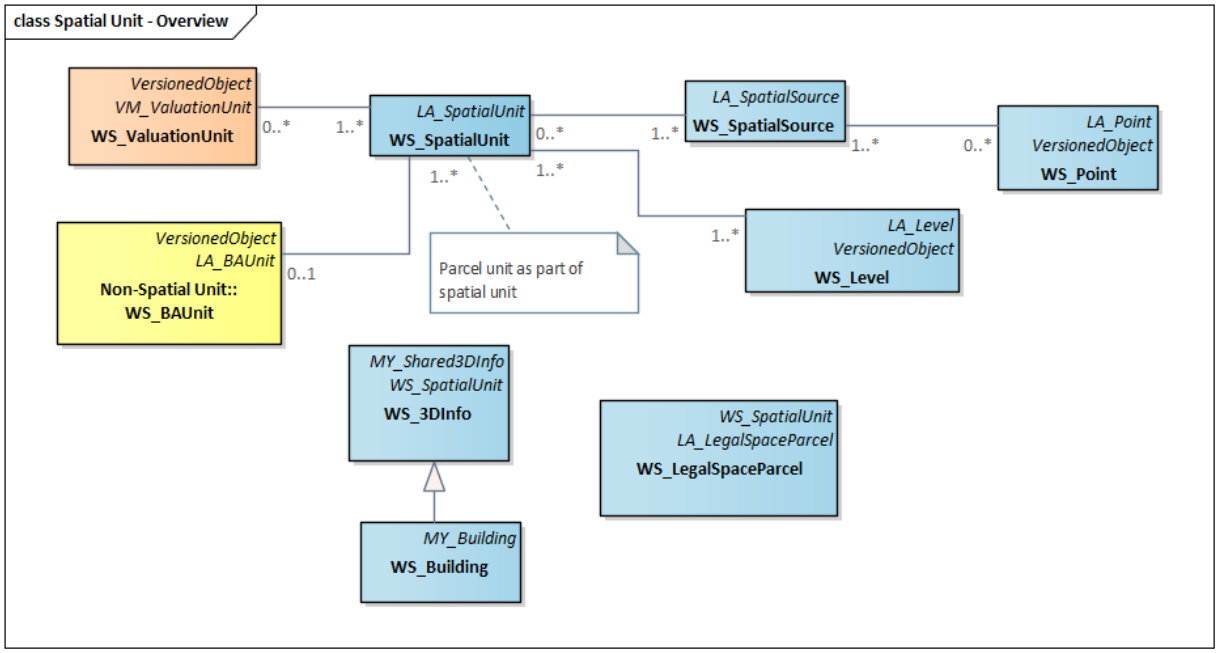


Figure 6: Overview of Spatial Unit for Wilayah Sarawak LADM Country Profile

3.4.3 Code Lists

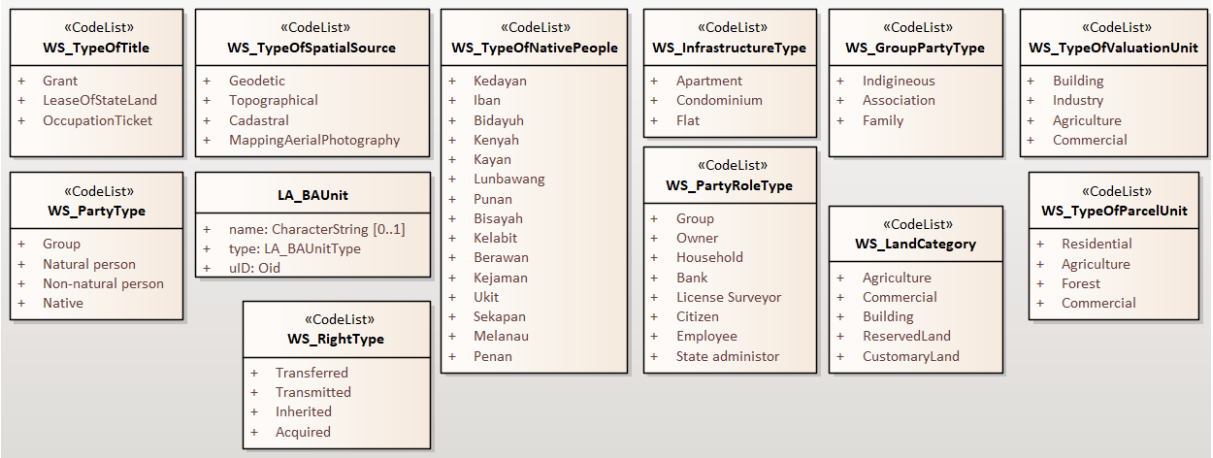


Figure 7: Code Lists of Wilayah Sarawak LADM Country Profile

Figure 7 represents some of the code lists for the Sarawak profile. Several values in these code lists have been incorporated from both the LADM and Malaysia Country Profile. Majority of the code list values were adopted, while some were introduced to align with Sarawak's administrative requirements. Notably, WS_PartyType has been expanded to include the 'native' value, which signifies the indigenous population in Sarawak. Additionally, WS_TypeOfNativePeople has been introduced to specify the various types of indigenous groups present in Sarawak.

4. CONCLUSIONS AND FUTURE WORK

The proposed Sarawak country profile is partly based on the existing spatial and administrative registration systems, and partly based on new developments inspired by the LADM standard. Based on the previous literature and the preliminary result, we believe there are good potentials to adopt LADM Edition II into Sarawak 3D LAS. Many countries have developed their country profiles, including Malaysia. Even though Malaysia has proposed and developed a country profile based on LADM, the developed data model can be extended for Sarawak LA. NCR is an official terminology utilized by the Sarawak legal systems. There is a difference in legal standing between Sarawak with Peninsular Malaysia where all the related branches (Land, Survey, Planning and Valuation) located under ‘one roof’ department – quite unique situation to be investigated for the LADM Edition II.

Hence, in this paper, we developed a country profile based on LADM Edition II for the Wilayah Sarawak. To be noted, the country profile still needs improvements especially in the aspect of 3D LAS with the relevant parts (part 4 – valuation and part 5 – spatial planning). It

is part of this project to get more relevant information and data from the stakeholders. This is also can be example to the other states or countries with the similar situations.

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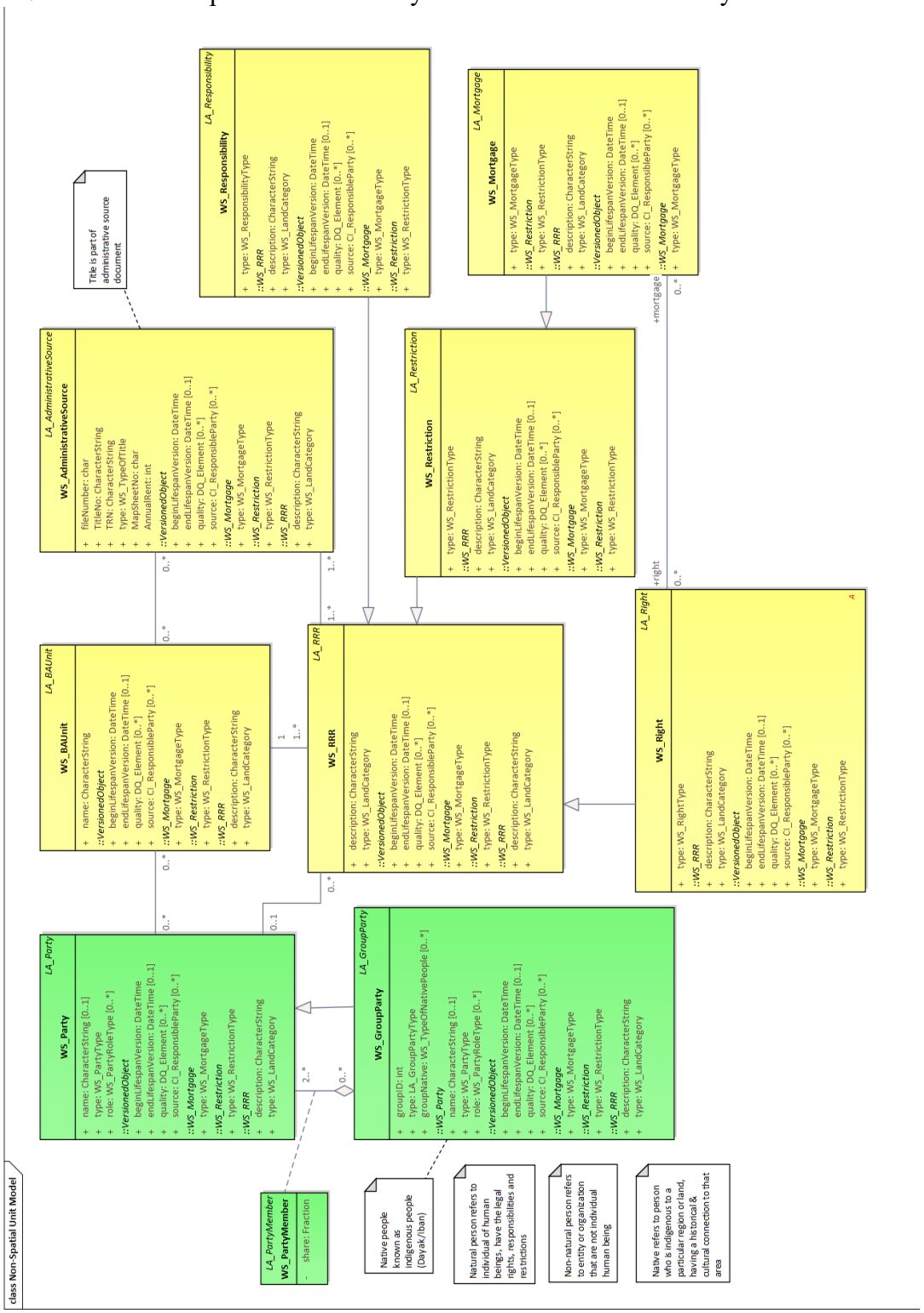
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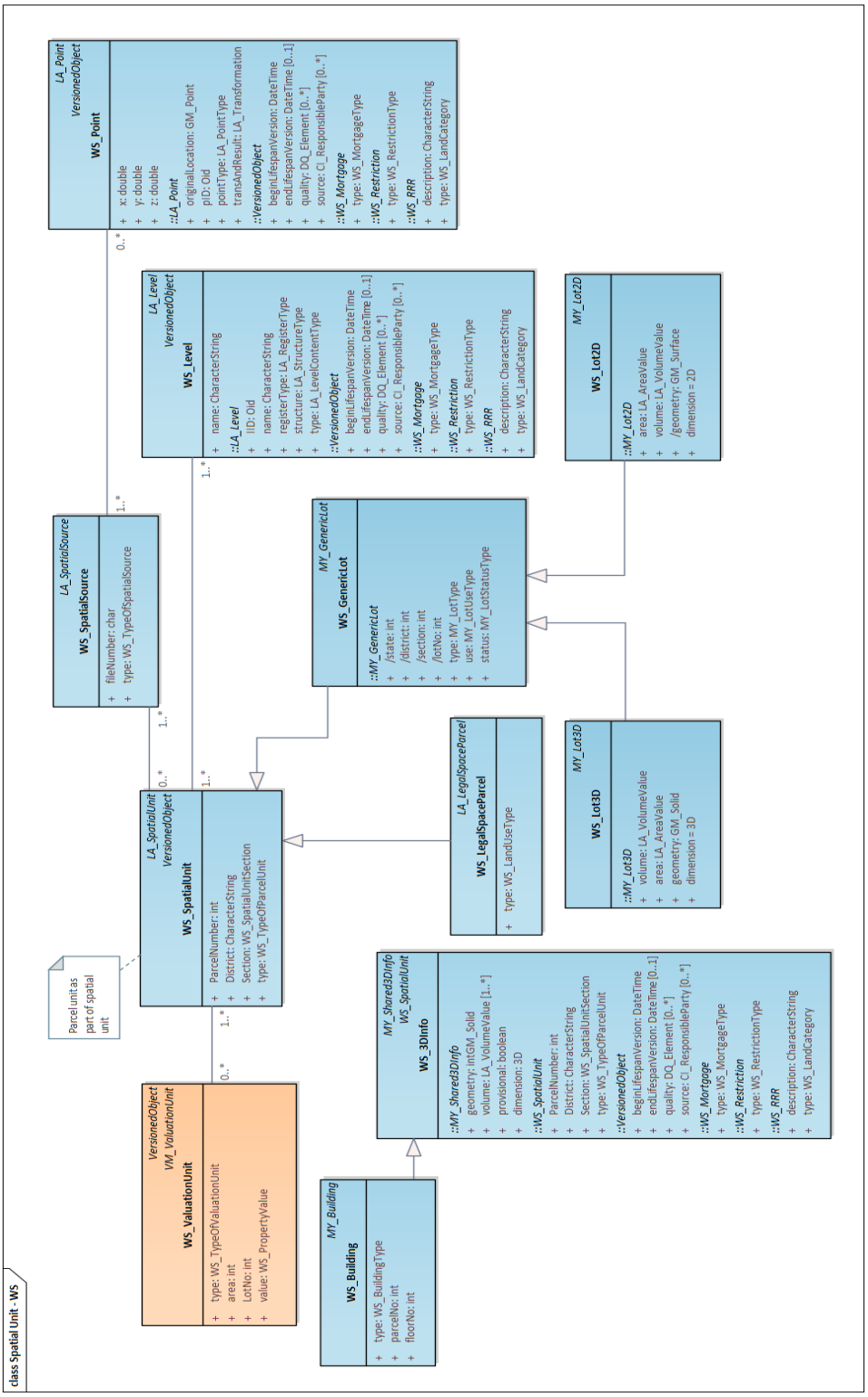
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APPENDIX A – Non-Spatial Part of Wilayah Sarawak LADM Country Profile



APPENDIX B – Spatial Part of Wilayah Sarawak LADM Country Profile



Identification of the three-dimensional legal aspects of Greek real estate legislation in the context of 3D LAS

Dionysia-Georgia PERPERIDOU, Dimitrios VAZOURAS, Ioanna KLOUKINA, Dimitrios PAPASTAMOU, Greece

Key words: 3D Greek Property LAW, 3D legal and technical aspects, 3D Greek LAS.

SUMMARY

The Greek Civil Code, which was introduced in 1946, was a major breakthrough in the Greek legal system, particularly its third book, which deals with Greek property law. Its rapporteur, Professor Georgios Balis of the Athens School of Law, considered that this new legal framework, on the one hand, was a continuation of the long-standing Byzantine-Roman law (in force since the 14th century) and, on the other hand, by limiting the rights to four - ownership, easement, pledge and lease - could effectively contribute to land management and stop the fragmentation of land and property rights. Greek property law itself is based on 3D descriptions of rights and their restrictions, which in many cases have not yet been rendered at a technical and/or spatial level, especially at the legal level. As a result, the 3D legal description of property rights and restrictions is not followed by the equivalent 3D technical and spatial description. Herein, is presented the 3D legal descriptions of property rights at the spatial level and within the basic framework of 3D LAS. The 3D interrelationships of Greek property law with other aspects of the Greek legal system related to real estate (rights, use, development, restrictions, rules) are analysed in detail. Special emphasis is given to the analysis of the interactions of Greek property law with urban planning legislation and the procedures for the recognition and identification of arbitrary constructions and the issuance of building permits, which have recently been revised at the 3D level. This approach can be the starting point for the design and implementation of 3D LAS in Greece, based on the public data base of the Hellenic Cadastre, as provided for in its founding law.

Identification of the three-dimensional legal aspects of Greek real estate legislation in the context of 3D LAS

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1. INTRODUCTION

The scope of land administration (LA) and land administration systems is to ensure sustainable development, especially under the demands of society for equal opportunities in terms of secure housing, access to education, work opportunities, food security, etc. (UN-FIG 1999; Dale and McLaughlin 2000; Steudler, Rajabifard, and Williamson 2004; Williamson et al. 2010; Lemmen, Van Oosterom, and Bennett 2015). At the same time, serious challenges or technological developments at the global level, such as global urbanisation (United Nations, Department of Economic and Social Affairs, Population Division 2019), climate change and reduction of energy consumption (Sussman 2008; United Nations 2020), urban air mobility affecting urban or spatial planning trends (Perperidou and Kirgiafinis 2023), integrated management of blue-green infrastructures (Ghofrani, Sposito, and Faggian 2017; O'Donnell et al. 2021) or underground space (Cui, Broere, and Lin 2021; Hámor-Vidó, Hámor, and Czirok 2021), are major challenges for LA and LAS. On the other hand, legal-technical descriptions on property rights and properties and restrictions or regulations on the use of properties, especially in the light of global challenges and technological developments, pose great challenges to LA and LAS, and especially when discussing their three-dimensional aspects. The development of 3D data types can also support and enhance the development of 3D cadastral systems (Germann, Lüthy, and van Oosterom 2018; van Oosterom et al. 2018; Kalogianni et al. 2020; Paasch and Paulsson 2023).

However, as there are different legal systems on the legal-technical definition of properties and relevant legislation on restrictions and regulations on the use of properties, the standardisation or unification of 3D properties, 3D RRR and relevant regulations and legislation is a major challenge (Paasch and Paulsson 2021; 2023). The 3D representation or real legal properties can also be challenging (Kitsakis et al. 2016), while the determination of boundaries in different jurisdictions leads to inhomogeneous spatial/cadastral data correlated with descriptive/legal definitions (Çağdaş et al. 2023). as land administration legislation varies from country to country, making it difficult to have a unified LAS at the global level, identifying the three-dimensional legal aspects of a country's real estate legislation can facilitate the establishment and implementation of country-based 3D LAS, especially in the case of countries that are currently developing their cadastral system but have a strong legal history and background on PL and property rights. Herein, is presented the 3D legal descriptions of property rights at the spatial level and within the basic framework of 3D LAS. The 3D interrelationships of Greek property law with other aspects of the Greek legal system related to real estate (rights, use, development, restrictions, and rules) are analysed in detail. Special emphasis is given to the analysis of the interactions of Greek property law with urban planning legislation and the procedures for the recognition and identification of arbitrary constructions and the issuance of building permits, which have recently been revised at the 3D level.

2. GREEK PROPERTY LAW

The Greek Civil Code, which was introduced in 1946, replacing the previous Byzantine-Roman law, introduced the Greek Property Law (GPL) Book 3, as a bundle of rules for the integrated legal and technical on properties and property rights, and at a three-dimensional level (Perperidou et al. 2021). The GPL determines the three-dimensional legal aspect of properties and property rights, through the categorisation of property rights, the restrictions on their exercise, especially for reasons of public interest, the application of rules for their efficient organisation and their publicity (Balis 1951; Perperidou et al. 2021) At the same time, the GPL completely separated the rules of immovable property and the rights exercised over it from the rules of spatial and urban planning, which had been dealt with in a uniform manner in the pre-existing Byzantine-Roman law. This separation not only facilitated the full implementation of the GPL, but also the proper implementation of spatial and urban planning and land management, but also created serious problems in correlating the legal-technical definition of property and property rights with land management, especially at the three-dimensional level.

Like all laws, Greek property law is constantly evolving, being redefined and reformulated in order to describe effectively and without exception the rights exercised or imposed over immovable property, as well as their limitations, in a complex and multi-level modern world. Furthermore, and because the various aspects of the Greek legal system, such as urban planning, the efficient organisation of rural areas, forestry legislation, expropriation legislation, the exploitation of natural resources, etc., can be better monitored through a solid and LAS. These needs have become more urgent with the introduction of cadastral surveying and the operation of the Cadastre in Greece since 1995.
In addition, as in the last decade, property rights that were abolished with the introduction of the Greek Property Code in 1946, such as the right of surface ownership, have been reintroduced in the case of private real estate of the public sector, public legal entities and other entities controlled by the public sector, as an optimal way to manage and use it, so that the public sector can respond adequately to the modern challenges of land management and the effective exploitation of its real estate, without having to lose ownership of it. Nowadays, with the completion of the Cadastre in Greece and the ever increasing and pressing need for the proper and effective organisation of space to ensure the sustainability of the man-made, natural and cultural environment in Greece, the 3D technical/spatial description of the legally described 3D property rights and their limitations in a 3D LAS perspective is of great importance.

2.1 3D Rights and Limitations under Greek Legislation An Overview

As presented by Perperidou et.al. (Perperidou et al. 2021), although under Greek legislation the legal aspects of 3D objects, 3D spaces, 3D rights and 3D restrictions on the use of real estate have been firmly described in legal documents and laws over time, their 3D technical representation does not exist, but only their partial 2D representation, Table 1.

Table 1: Legal and Technical 3D Rights & Restrictions on Properties Comperative Analysis (Source: Perperidou et al. 2021).

Thing/ Right/restriction	Legal Framework	Legal Binding Document	3D legal description	3D Representation
Immovable thing	PL	Deeds/ official governmental or administrative acts	YES	No/ Only 2D boundary drawing
Ownership right	PL	Deeds/ official governmental or administrative acts	YES	NO
Property division - horizontal/ vertical/ vertical combined to horizontal	PL/ L.3741(1929)/ urban plannig regulations	Deed	YES	NO/ 2D boundary drawing and 2D top views, cross section & longitudinal model
Trees (rights-restrictions)	PL / urban plannig regulations	Under conditions in Deeds or officially approved building permit	YES	NO/ in some cases of building permits only 2D position
Rain water natural flow agricultural areas	PL	In some cases by court decision	YES	NO/ 2D legal description in court decision
Rain water natural flow residential buildings	PL	None	YES	NO/ Under conditions in 2D top views, cross section & longitudinal model of officially approved building permit
Spring/ Sping village water supply	PL	Deeds/ court decisions	YES	NO/ 2D bounary or water supply network drawing
Rights of way	PL	Deeds/ official governmental or administrative acts/ court decision	YES	NO/ 2D width length topographic diagram
Utility Network Easement	PL/ specific legislation on utility networks legal entities	Court decision (on the bases of expropriation rules)	YES	NO/ linear determination, width discribed by word content - hight or depth discribed by word content
Mines	PL/ L. ΓΦΚΔ (1910)/ Mining Code (1973)	Official administrative permit	Yes	NO/ 2D detailed topographic map of surface boundaries, word content on 2d surface boundaries ulimited underground extension
Expropriation	PL/ Expropriation Code	Official administrative acts after court decision	Yes	NO/ 2D detailed topographic diagram of boundaries and all things firmly connected to the ground (over or under)
Seashore & beach borderline	PL/ L. on Seashore and Beach	Official administrative decision	YES	NO/ 2D detailed topographic diagram, seashore borderline can enter the sea in case of officially approved constructions
Surface ownership right	L. 3986 (2011)/ urban plannig regulation	Contract after offcial administrative decision or law	YES	NO/ 2D detailed topographic diagram of property boundaries on which surface owership right is exercised/ 2D top views, cross section & longitudinal model of officially approved building permit

Furthermore, 3D environmental restrictions that are provided in both urban legislation and PL are not adequately technically represented in 3D level, (Perperidou and Xydopoulos 2021), while currently there are serious inconsistencies amongst 2D cadastral spatial data and 2D urban plans technical provisions, causing serious problems in urban development and overall land administration in Greece (Perperidou 2023). Similarly, the lack of correlation between the legal descriptions of property rights in Greece's Cadastre and their spatial evolution over the years can cause a number of problems in land administration, especially after major disasters such as the catastrophic Mati and Kokkino Limanaki forest fires of 2021, which claimed the lives of 102 people and left many more injured and homeless (Perperidou 2020). It is worth noting that the redevelopment of the Mati and Kokkino Limanaki areas under firm urban and spatial planning regulations has not been achieved so far due to the lack of solid and official 3D spatial data and a firm 3D LAS.

Moreover, since 2011, all real estate transactions in Greece must include a technical description of the status of the property in terms of the legal provisions on building permits, the existence of any structures that should be legalised, and the legalisation process includes a

series of 2D top views, cross-sectional and longitudinal models, while since 2021 the Building Electronic Identity is mandatory in any real estate transaction. In parallel, and since 2018, all building permits will be issued through an electronic system that requires the submission of the official topographical plan of the parcel referenced to the official Greek reference system (EPSG 2100). In cases where there is a discrepancy between the official topographical plan of the permit and the 2D cadastral spatial documentation of the plot/land parcel, the permit may not be issued, resulting in a loss of time and money for the landowner.

In addition, a series of decisions of the Council of State in 2023 regarding the validity of issued building permits in relation to the status of the road network of outer urban and rural areas where no urban plans are in force, has put on hold not only the issuance of urban permits, but also property transactions. In the context of these developments, the Greek government was forced to announce the acceleration of spatial planning through Local Urban Plans - LUP (only 33% of Greece's territory is covered by LUP) and to launch, by presidential decree, an extensive technical programme for the official recognition of existing roads in outer urban and rural areas in order to overcome the problems raised by the Council of State.
The catastrophic floods of September 2023 in Thessaly, which claimed the lives of 18 people and more than 100,000 domestic animals, leaving thousands homeless and jobless, due to the extensive flooding of some 720 square kilometres of highly productive farmland and pastures, and which cut the country in two as the national road and the railway linking Athens to Thessaloniki were put out of service, with the estimated cost of recovery running into billions (Kantouris 2023), brought the need for integrated spatial planning, property rights and land management to the center of the debate. It is worth noting that in Thessaly the refugees of the 1922 Minor Asia catastrophe were settled, so there was a comprehensive plan of urban/settlement network and rural land organisation, accompanied by the desiccation of Lake Carla, which after 2000 is in the process of regeneration (after the flood is fully regenerated), while there are certain issues and questions about the state's policies on water resources management, flood protection works and the overall land administration process and implementation of legislation, while there are growing voices demanding large scale settlements relocation.

3. 3D PROPERT RIGHTS IN GREECE FROM THE PERSPECTIVE OF 3D LAS

Both the GPL and the cadastral legislation have specific provisions on properties and the exercise of property rights in relation to the common interest and the common good, constituting a sphere of public power in the exercise of private property rights and ensuring the sustainable development of Greece through the precise spatial definition of parcels and the restrictions/regulations imposed on them (Balis 1951; *Law 2664 on Hellenic Cadastre Operation* 1998). However, there is still no fixed technical description of the properties, such as plots/land parcels /buildings/condominiums - separate ownership and property rights, nor of the rules/regulations and restrictions imposed on the properties, which leads to a number of problems and complications for property use, land management and land administration, as analysed in Section 2 and Subsection 2.1.

Due to the specificities of the GPL and the National Cadastre legislation, and their integration with relevant legislation on regulations or restrictions of property rights imposed by urban and spatial planning legislation, forestry legislation, agricultural legislation and even water management legislation, it is preferable to analyse their 3D aspect in the context of a future Greek 3D LAS, rather than to adapt it to an existing prototype.

3.1 3D Property Rights in Greece and 3D LAS

As mentioned above, the GPL covers not only the legal but also the technical aspects of property and property rights in a three-dimensional level. The definition of immovable property also includes basic provisions on land management in the public interest, as shown in Figure 1.

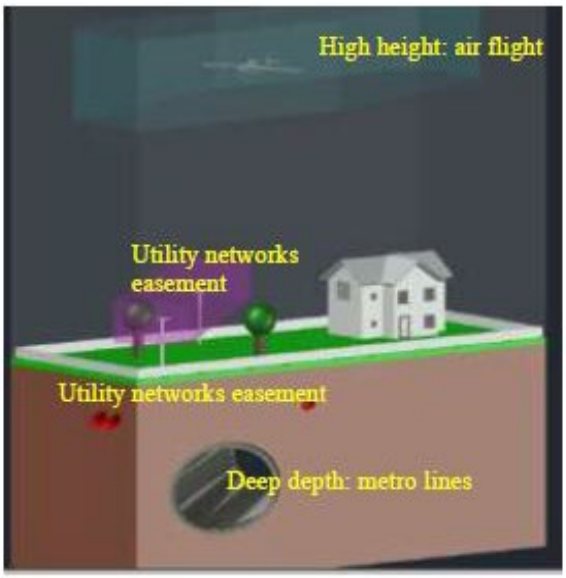


Figure 1: Immovable think and ownership right according to Greece's PL and common good restrictions (Source: Perperidou et al. 2021)

The GPL itself contains clear provisions on water resources management (Perperidou et al. 2021), environmental pollution and zoning (Perperidou and Xydopoulos 2021), urban planning implementation (Perperidou et al. 2021; Perperidou and Xydopoulos 2021), utility networks easements (Perperidou et al. 2021), mine development and underground network development (Perperidou et al. 2021; Perperidou, Sigizis, and Chotza 2021) which can be displayed in 3D. In parallel, official administrative acts such as urban and spatial plans, including those of the Ministry of Agriculture, sea and beach borders, expropriations, which are approved by presidential decree and represented in 2D detailed topographic/cadastral diagrams, which are not always referenced to the official Greek reference system (ESPG 2100) (Perperidou et al. 2021).

Furthermore, the operational cadastral base or the ongoing cadastral survey presents inconsistencies, on the one hand, in the integration of the official acts diagrams into the Hellenic Cadastral Database, and on the other hand, in the accurate representation of the parcel/plot boundaries due to acceptable accuracy deviations that are foreseen in the cadastral survey but are prohibited in the operational cadastre. These inconsistencies are the result of

medium or large errors during the cadastral survey, but also due to transformation errors between the different reference systems used in Greece and the current one, the ESPG 2100 (Ampatzidis, Kotsakis, and Katsambalos 2011; Moschopoulos et al. 2020). Thus, for the 3D representation of property rights, properties and spatial objects in general, transformation errors and standard deviations need to be taken into account. Thus, and with respect to the 3D LAS principles and models as presented by scholars (e.g. (Kalogianni et al. 2020), the basic principles of geodesy and reference systems must be taken into consideration when it comes to the 3D representation of property rights, properties and administrative acts in Greece, by adapting the current cadastral database, either the operational Cadastre or the ongoing cadastral survey, to these principles. According to the provisions of the 3D LAS system, the 3D representation of property rights in Greece should provide for and include the following:

- Plot/ land parcel 2D depiction in respect to reference systems transformations principles/ equations (in respect to ESPG 2100)
- Plot/ land parcel vertical depiction in respect to reference systems transformations principles/ equations (in respect to ESPG 2100)
- Adjustment/ correction of existing cadastral parcels to reference systems transformations principles/ equations (in respect to ESPG 2100).
- Plot/ land parcel use or main use
- Plot/ land parcel legal documentation (titles, deeds, other legal binding documents etc.)

With regard to property restrictions/regulations imposed by official legislation, e.g. urban and spatial plans, building codes, protection of cultural heritage, protection of forests, management of water resources, etc., or by official acts that are still in force, e.g. land distribution or redistribution to farmers, easements for utility networks, expropriations, exploitation of mines, etc., and according to the provisions of the 3D LAS system, the 3D representation of Greek restrictions and regulations on properties/property rights should provide for and include:

- 2D official plans/ cadastral – topographic diagrams depiction in respect to reference systems transformations principles/ equations (in respect to ESPG 2100)
- Official plans/ cadastral – topographic diagrams vertical depiction in respect to reference systems transformations principles/ equations (in respect to ESPG 2100)
- Adjustment/ correction of existing cadastral parcels/ spatial entity/ spatial layer to reference systems transformations principles/ equations (in respect to ESPG 2100)
- 2D spatial distribution or prediction maps or natural phenomena (e.g. water resources management, flooding prediction, cold or hot spots of various phenomena, etc.) in respect to DTM/ vertical depiction with direct reference to systems transformations principles/ equations (in respect to ESPG 2100)
- Legal documentation of official acts
- Legal documentation of development/ sustainable development principles/ goals/ axes

Based on the above-mentioned 2D representations of either properties/property rights or institutional regulations and their vertical representation, 3D parcels or volumes can be created and form the basic level of the 3D LAS of Greece. Thus, not only the legal spaces would be adequately described, but also they would be adjusted to the concurrent values and statuses or the official reference system, facilitating either the 4D (including time) transition

of the 3D LAS or the geodetic adjustment/correction/modification of the 2D vertical aspect of those 3D legal spaces to the concurrent geodetic conditions of the official reference system diversification - evolution.

3.2 Building Code and Identification of Arbitrary Structures in Greece in the Context of 3D LAS

The Greek Building Code includes the entire regulatory framework for building regulations, while its detailed and analytical technical specifications are officially documented by the General Building Regulations, the Sanitary and Environmental Regulations, which are issued by Ministerial Decisions officially published in the Official Gazette of the Hellenic Republic. Building permits should follow not only the regulations and specifications of the Building Code, but also the regulations/provisions of urban/spatial planning, especially with regard to the volume and height of buildings and their use.

Both the Building Code (including its specifications) and urban/spatial planning are periodically amended and modified, resulting in the diversification of institutional regulations/restrictions on real estate construction activities over the years.

Since 2011, and following the implementation of legislation on the legalisation of arbitrary constructions, all building permits and property transactions must identify and include any arbitrary construction that should be legalised first. However, as building permits are issued in different years, when different building, urban or spatial planning regulations were in force. Thus, the determination of the chronological evolution of both the Building Code and the Urban or Spatial Planning regulations in 3D level is essential not only for the determination of the legal or arbitrary constructions and the precise building volume, but also for the issue of concurrent building permits, especially in plots/land parcels with existing building activity.

Moreover, the spatio-temporal identification of building volumes and buildings in general is the fundamental element of LA and the initiation of development programmes such as the transfer of development rights (Perperidou et al. 2020) and the land bank, which is foreseen in the current Building Code as a prerequisite for the completion of the legalisation of arbitrary constructions.

According to the Greek legal framework, not only in the concurrent past but also in the past, building permits provide basic technical but also firm legal commitments on the legal status of the plot/land bank in terms of GPL and property rights, as well as its urban planning status (e.g. building factor, maximum building height, building use, etc.) and its status in terms of restrictions imposed by various government agencies such as the Archaeological Service, the Water Resources Authority, the Ministry of Agriculture in the case of land bank in rural areas.

After 2011, all topographic maps submitted for building permits must be referenced to the official Greek reference system, ESPG 2100, at a scale of up to 1/500, and should be mandatory:

- Detailed 2D topographic depiction of the plot/ land parcel and its area with direct reference to its legal status (titles, owners, etc.). In case of operational Cadastre the plot's/ parcel's cadastral code
- Detailed 2D topographic depiction of the existing or the future buildings
- Altimetric curves
- Urban plan's institutional lines, e.g. building line, building distance from boundaries and facade, etc. and extract from the urban in the area

- Building regulations and restrictions, e.g. building factor, maximum building height, maximum building surface coverage, building use or plot's/ land parcel's non buildable zones etc.
- Distance from streams, rivers, seashore, utility networks easements or any other institutional borderline that might restrict building activities
- Archeological agency approval in case of plots/ land parcels located in declared archeological areas or in case of listed building

Besides the detailed topographic diagram building permits also obligatory include:

- Building diagram in which the building volume as 2D representation and vertical section
- Top views of each floor and cross sections of all building sides, as well as longitudinal model a sketch
- Reinforced concrete views for each floor and the foundations
- Utilities network routing top views for each floor
- Building permit official license

All building permit documents and drawings are submitted to the State's official platform for issuing building permits in pdf format. In the case of the legalisation of arbitrary constructions, the official topographic plan, the design plan, as well as the top views and sections of the building permit must be adapted to the current Greek Reference System (ESPG 2100) and any deviation between the official building permit and the actual construction must be documented in drawings, legally described in a technical report and submitted to the State's official web platform for the legalisation of arbitrary constructions in pdf format. In this context, the issuing of building permits and the legalisation of arbitrary constructions in Greece include the main principles of LA in 2.5 dimensional aspect, even though the concurrent legal framework refers to 3D legal spaces and objects. Thus, a Greek 3D LAS that would include building permits and legalisation of arbitrary constructions must have detailed information on the official spatiotemporal evolution of building volumes together with the detailed spatiotemporal diversification of official building regulations and restrictions, including specific geodetic rules on reference systems transformations and evaluation.

4. CONCLUSIONS

In Greece, both property law and land law, as well as technical legislation as it is specialised at the level of urban planning, management of natural resources such as water, expropriation, definition of the seashore, etc., are not limited to the technical dimension, but affect the clear and strict legal definition of 3D spaces and 3D objects. And it is precisely this precision of the technical and legal definition of 3D spaces and objects of technical and real estate legislation in general that makes it a potential LAS, which has not been fully and unified by 3D spatial and topological rules. Even the process of issuing building permits and dealing with unauthorised buildings is in itself a process that is subject to LAS rules for each individual property, even if it is still at the 2.5 level. Consequently, any process of consolidation or its implementation under a Greek LAS and even 3D may be less complex than one might imagine.

Future research should focus on the refinement of topological rules at the 2D and 3D levels, taking into account the strict rules of geodesy and transformations between reference systems, as a multitude of administrative acts and institutional lines are embedded in the previous reference systems. The substantial connection between the current and previous reference systems can be the first step for the construction of an integrated 3D LAS in Greece, in which the documentation of spatial information can also be legally guaranteed, while 3D legal spaces and 3D legal objects can be attributed with spatial accuracy, enabling the development of a 3D LAS.

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Requirements Based Design of the LADM Edition II

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Key words: LADM, ISO, 3D

SUMMARY

This paper examines the requirements based design of the LADM Edition II. The requirements are the starting point for the Abstract Test Suite (ATS, Annex A in an ISO standard). The requirements/ATS can be used to assess if a given LADM country profile with a specific application schema is conformant with the LADM standard. The requirements are a new aspect of ISO standards and this offers several benefits:

1. requirements express explicitly the needs from experts in the domain,
2. requirements are a very concise manner to describe the content of the standard,
3. requirements are used to introduce of the actual standard content (in the case of LADM, part of the UML class diagram), and as mentioned above,
4. requirements form the basis of the ATS.

This paper describes the new structure of the second edition of the standard and the capabilities of this new edition, which is organized in multiple Parts (standards addressing a specific part of the scope) and Packages (groups of conceptually closely related classes, i.e. with relative high number of associations between the classes from one package compared to the number of cross package associations), with a particular attention to the requirements and design related decisions taken in the revision process.

Requirements Based Design of the LADM Edition II

Abdullah KARA, Christiaan LEMMEN, Eftychia KALOGIANNI and Peter VAN OOSTEROM, The Netherlands

1. INTRODUCTION

The Land Administration Guidelines by the United Nations Economic Commission for Europe (UNECE) include a widely accepted definition of land administration: "*the processes of recording and disseminating information about the ownership, value and use of land and its associated resources*" (UNECE, 1996). Based on this definition the LADM standard defines land administration as the "*process of determining, recording and disseminating information about the relation between people and land*". Land is defined in the LADM Edition II as the "*spatial extent to be covered by rights, restrictions and responsibilities and encompass the wet and dry parts of the Earth surface, including all space above and below*". Inclusion of the marine georegulation, land value information, as well as spatial plan information in LADM is well aligned to those definitions. From these definitions it can be seen that LA is a broad field with several functions, as introduced by Enemark (2006). In all these functions the 3D representations play an important role.

The Edition I of the Land Administration Domain Model (LADM) is published by ISO as an International Standard (IS) in 2012. It provides a shared ontology, defining a common terminology for land administration (Lemmen et al., 2015). The Edition I includes both support for 3D representations of spatial units and a seamless integration of 2D and 3D spatial units (Lemmen et al., 2010). The 3D capabilities of LADM have been used and reported in a range of publications, from visualizing and querying 3D properties through a 3D platform, to BIM-based applications for 3D LA and 3D property valuation (Ying et al., 2011, Karki et al., 2011, Jeong et al., 2012, Felus et al., 2014, Zulkifli et al., 2015, Dimopoulou et al., 2017, Shnaidman et al., 2019b, Kalogianni et al, 2020, Alattas et al., 2021).

Although the LADM Edition I is extensively used (Kalogianni et al., 2021) and is applicable for various use cases and purposes, ISO rules prescribe periodic review. This started with a meeting of the UN-GGIM Expert Group on Land Administration and Management that was held in 2017, in Delft, The Netherlands. It was concluded that a revision of the LADM Edition I is required in order to provide better tools in support to tenure security with better coverage of LA (UN-GGIM, 2019). As a result of the voting on the systematic review of ISO 19152:2012 (March 2018) it became clear that the majority of the ISO/TC 211 P-members expressed their wish for the revision. Therefore, the ISO Stage 0 project started in May 2018 during the 46th Plenary Meeting Week of ISO/TC 211 in Copenhagen, Denmark.

In order to revise LADM Edition I, several FIG LADM Workshops were organized, where options for improvement and extensions were discussed among experts; see further inputs (needs) for Edition II in FIG (2018), Lemmen et al. (2019) and Lemmen et al. (2020). In the 48th Plenary Meeting Week of ISO/TC 211 (June 2019), Standards Council of Canada (SCC)

proposed LADM Edition II as multi-part. The following structure for the multi-part option (as multiple coherent packages with every part in separate standard) has been agreed:

- Part 1 – Generic conceptual model
- Part 2 – Land registration
- Part 3 – Marine georegulation
- Part 4 – Valuation information
- Part 5 – Spatial plan information
- Part 6 – Implementation aspects

The Parts 1, 2, 4 and 5 are the Parts in which the authors are currently involved. Part 1 will be a high-level umbrella standard; Part 2 is largely based on LADM Edition I and focuses on land registration, with an enhanced support of surveying functionality, including new subclasses of spatial unit, and extended 3D spatial profiles. Part 3 harmonizes the description of rights, restrictions and responsibilities (RRRs) and aligns land concepts with marine aspects from the marine domain based on IHO S-121 Maritime Limits and Boundaries Product Specification. Part 4 concerns valuation information in the context of land administration, while Part 5 deals with spatial planning information and includes the planned use of the land (zoning), resulting in RRRs. Lastly, Part 6 is planned to be about implementation of the LADM and will be developed in close collaboration with OGC.

The methodology used in the revision of the LADM is the Design Research Methodology, which is consistent with the ISO methodology for the development of standards. To mention the main steps of the ISO methodology, starting with the fact that standards should contain a set of requirements that form the basis for the scope of the standard and are further used to specify an abstract test suite. In addition, the code list values of each class of the standard should have a description and, where appropriate, references to the source of these definitions should be added. These ISO steps were not followed in the development of LADM Edition I and therefore directly impact the design and structure of all parts of Edition II.

The remainder of the paper is organized as follows: Section 2 presents the needed for requirements in ISO standards and the approach we followed. Section 3 then presents the requirements and package structure of LADM Edition II. A reflection on the decisions made during the requirement-based design of LADM Edition II is given in Section 4, together with the conclusion.

2. REQUIREMENTS IN ISO STANDARDS

Within ISO the use of requirements has become obligatory quite recently. Initially the editors were not that enthusiastic about adding one more task to the revision job(s). However, when implementing the opinion changed and the importance of the requirements was recognized and even highly appreciated. Actually, in the PhD thesis of Lemmen (2012), the basis of LADM Edition 1, requirements were already introduced. However, they were kept outside the standard itself. So, this thesis was the starting point for the requirements in parts 1 and 2. For requirements in parts 3, 4, and 5, experts from the various domains were consulted:

hydrography (via the IHO), valuation (via FIG comm.9 and RICS) and spatial planning (via FIG comm. 8).

In Edition 1 of LADM and in the first WDs of Edition 2 the requirements were not included. In the fall of 2022, the requirements have been first introduced in the various versions (CD, DIS) of the various parts (1 to 5). In the first half of 2023 balloting and commenting of the various parts have been received and processed. This resulted in a second set of more refined requirements, which are presented in the next section. In the first attempt there were some flaws:

- complex requirements, actually consisting of multiple requirements,
- partly overlap in constraints, just different wording, but same intention,
- missing constraints, part of the LADM Edition 2 not covered by requirements,
- wrong wording, as ISO typically require requirements to use 'must' or 'shall' and not lighter verbs.

3. SPECIFICATION OF THE REQUIREMENTS

The LA paradigm with the different functions, land tenure, value, use and development has been around for years (see UNECE, 1996; Enemark, 2006), but there was not a detailed model to support the refinement, development and implementation of LA functions. LADM Edition I was mainly focusing on land tenure. In this context, LADM Edition II aims to fill this gap by extending the scope of the first Edition with land value, use and development. This paper describes the harmonization of requirements distilled from the comments of the ISO TC/211 member states, the workshops and other meetings and sources (see below) and grouping them as basis for the different parts of LADM Edition II..

The distilled requirements used to design the packages are shown in the Tables 1 to 5. The requirements specified in Part 1 apply also to the other parts (i.e., Parts 2, 3, 4 and 5) as they are all based on the definitions of Part 1. It should be noted that Part 1 has been submitted for FDIS stage while Part 2, Part 4 and Part 5 will be submitted for DIS stage before the end of 2023. Therefore, the requirements may change over time during the voting and commenting rounds. The requirements in the tables are colored using the colors shown in Figure 1 to indicate the various packages. As far as the coloring of the table and Figure 1 is concerned, green has been chosen for the Party package, yellow and blue for the Administrative and Spatial Unit packages respectively, and light pink for the Survey and Representation sub-package (as in the earlier LADM publications). For the parts introduced in Edition II, different colors are used; the packages of Part 3 are colored grey, while Part 4 and Part 5 are colored orange and light blue respectively. Some requirements have been label generic and these are ‘colored’ white, this mainly applies to the requirements in Part1, but there are also some generic requirements in Part 2.

Most requirements in Table 1 and Table 2 are based on Lemmen (2012), ISO (2012) and Lemmen et al. (2015), but refined in the ISO standardization process during the development of LADM Edition II, Parts 1 and 2.

Table 1. The proposed requirements for LADM Edition II Part 1

Requirement name / Solution	Requirement Description
Requirement 1-1 'Core Class Conformant'	**LADM-based systems can be designed based on core LADM classes.** The description, development and refinement of efficient and effective land administration/georegulation systems using this part of ISO 19152 shall be compatible with the classes described in Clause 5 (Party, Administrative and Spatial Unit Packages), and the classes and attributes described in Clause 6 (LA_Source and VersionedObject).
Requirement 1-2 'Triplet Structure Present'	**All people-to-land relationships can be managed** The three, possible compound, elements 1. LA_Party – 2. LA_RRR and/or LA_AdministrativeSource[1] – 3. LA_BAUnit/ LA_SpatialUnit provide the common pattern for land administration/georegulation and form the basic structure. A land administration/georegulation system shall be constructed using groupings of LA_SpatialUnit, LA_BAUnit and/or LA_Party classes.
Requirement 1-3 'Backwards Compatible'	**Compatibility between the versions** Any country profile established using the elements defined in conformance with ISO 19152:2012 shall remain conformant with this version of the standard[2].
Requirement 1-4 'Versioned Objects'	**Maintenance of history should be supported** All land administration/georegulation systems shall support (bi-) temporal data management by inheritance from LA_VersionedObject.
Requirement 1-5 'Oid Present'	**All subjects, sources, objects etc. can be identified** The local object identifier (Oid) shall be unique within the namespace.
Requirement 1-6 'Source Document Present'	**Reference to source documents should be supported** All land administration/georegulation systems shall make use of the LA_Source class to support references to source documents.

The first eight requirements in Table 2 are not colored, as they are general requirements that apply to all packages in Part 2.

Table 2. The proposed requirements for LADM Edition II Part 2

Requirement name / Solution	Requirement Description
Requirement 2-1 'Based on General Conceptual Model'	**All requirements in Part 1 apply to Part 2** This part of the standard is based on Part 1 – General Conceptual Model. All requirements contained in 19152-1 shall apply to this part of the standard.
Requirement 2-2 'Continuum of Rights'	**All rights should be specified in a seamless way, not only real rights, also customary and personal rights.** The Continuum of Land Rights shall be supported. This includes the recognising, recording, administering a variety of appropriate and legitimate land tenure forms, such as

[1] In some jurisdictions, deeds registries only record deeds/administrative sources. They do not have records of RRRs. Also, in some common law jurisdictions, transactions may refer to a survey plan/spatial source (and not a parcel number/spatial unit). The relationship between the party and the spatial unit is established by a legal instrument (source).

[2] This implies that also normative references as used in ISO 19152:2012 are also used in 19152-1 or updated versions of the reference (i.e., ISO 19103, ISO 19105, ISO 19107 and ISO 19109).

	registered freehold, lease, group tenure, adverse possession, occupancy, customary.
Requirement 2-3 'Grouping People Land'	**Grouping people and land** Groupings of people and land shall be supported. The flexibility of LA model can be based on the recognition that people to land relationships appear in many different ways, depending on local tradition, culture, religion and behaviour.
Requirement 2-4 'Different Organisations'	**Distributed environment** Land administration data can be maintained by different organisations. And within one organisation at many sites. Administrative territories for organisations can be completely different. The LADM based systems shall be implemented as a distributed set of (geo-) information systems, each supporting the maintenance processes (transactions in land rights, establishment of rights, restrictions and responsibilities) and the information supply of parts of the data set, represented in this model.
Requirement 2-5 'Keep Data to Source'	**No duplications unless something has different meanings in different models (roles)** Land administration data shall be kept to the source within Spatial Data Infrastructure (SDI). Today all data (spatial and thematic) can be stored in a Data Base Management System (DBMS). Information products are becoming flexible combinations of digital data components and additional facilities and services. This can replace the exchange of copies of data sets between organisations. Multi source information products require avoidance of redundancy and good standardisation protocols.
Requirement 2-6 'Authentic Source Documents'	**Continuous source updates maintenance; see also Requirement 1-6** Inclusion of new data and data updates shall be documented. This concerns legal administrative data, spatial data and/or technical data.
Requirement 2-7 'Transparency'	**Transparency in history management and updates** All updates shall be traceable in LADM compliant LASs
Requirement 2-8 'Responsible Person'	**Responsible person should be part of source data** The names of persons responsible for transactions shall be part of the source data set (conveyors, surveyors, registrars, etc.). This is one reason for management of history and for documentation of all updates.
Requirement 2-9 'Continuum of Right Parties'	**All right holders should be clearly identified** Efficient and effective LAS using this part of ISO 19152 LADM shall support all types of parties. Parties can be persons, or groups of persons, or non-natural persons, that compose an identifiable single entity. A non-natural person may be a tribe, a family, a village, a company, a municipality, the state, a farmer's community/co-operation, a slum dwellers group/organisation, a religious community, and so on. This list may be extended, and it can be adapted to local situations, based on community needs.
Requirement 2-10 'Basic Administrative Unit'	**Spatial units that have the same right should be grouped together** In combination to the Triple (1. LA_Party – 2. LA_RRR and/or LA_AdministrativeSource – 3. LA_BAUnit/LA_SpatialUnit) the constellation of basic administrative units shall be supported. The purpose of a baunit is the grouping of spatial units, which have the same rights, etc. attached. A baunit can play the role of a party: a baunit may be owned by one or more other baunits.
Requirement 2-11 'Shares In RRR'	**Shares in right should be supported** Holding shares in rights, restrictions, responsibilities shall be supported.
Requirement 2-12 'Continuum of Spatial Units'	**All spatial units should be specified in a seamless way** Representation of a broad range of spatial units, with a clear quality indication, shall be supported by an LADM compliant LAS. Spatial units are the areas of land (or water – e.g., water rights and the marine environment) where the rights and social tenure relationships apply. Spatial units can be represented as a text ("from this tree to that river"), as a sketch, as a single point, as a set of unstructured lines, as a surface, or as a 3D volume.
Requirement 2-13 'Spatial Unit Identifiers'	**All spatial units should have a unique identifier** Spatial units shall have a unique identifier. A key component in LASs is the spatial unit identifier, the parcel identifier or the unique parcel reference number. This acts as a link between the parcel itself and all record related to it. It facilitates data input and data exchange. There can be a need to change identifiers during data collection.

Requirement 2-14 'Spatial Source Based Maps'	**Cadastral maps should be based on surveys** Cadastral maps shall be based on spatial sources, such as surveys, design sources, topographic maps, etc.
Requirement 2-15 'Data Acquisition Methods'	**Different data acquisition methods can be used to identify boundaries of spatial unit** Surveying of boundaries shall be supported. Surveys may concern the identification of boundaries of spatial units on a photograph, an image, or a topographic map. Surveys can be conventional land surveys, based on hand-held GPS. In all cases the representation of 'legal' reality is differentiated from the 'physical' reality. There may be sketch maps drawn up locally. Depending on the local situation, different registrations or recordings of land rights are possible.
Requirement 2-16 'Cadastral Reference System'	**Cadastral surveys should be represented in a reference system** Efficient LASs compliant with this part of LADM shall be capable of producing co-ordinates, forming an essential component of cadastral systems. Provisions may be made to accommodate future changes in the reference system that may occur as a result of technical improvements. These may affect all co-ordinate-based systems. Imagery can be used depending on the user requirements, cost, and timing among other factors. It can be possible to include all documentation on data collected as evidence from the field.
Requirement 2-17 'Data Quality'	**Quality of cadastral data should be specified** The cadastral information shall be as complete as possible, reliable (which means ready when required), and rapidly accessible. Users of cadastral information need clarity, simplicity and speed in the registration process. Consistency between spatial and legal administrative data is important. Topology integrated with geometry and other attributes is relevant. The system must be ready to keep the information up to date. Data quality of spatial data may be improved in a later stage of development of a LAS, this has to be documented. For combined data products from different sources the quality descriptions and meta data related to the original data are relevant in relation to liability and information assurance.

Table 3. The proposed requirement for LADM Edition II Part 4

Requirement name / Solution	**Requirement Description**
Requirement 4-1 'Core LADM Conformant'	**A land administration system specifically designed for valuation information should be based at least on the ISO/TC 211 set of standards** Efficient and effective land administration system for valuation information compatible with this part of ISO 19152 LADM shall be modelled using or extending the core LADM concepts, namely party, RRR, BAUnit, spatial unit, versioned object, which are all based on source documents. This statement also implicitly implies that it should be modelled in accordance with ISO standards including ISO 19107 — Spatial schema, ISO 4217 — Currency codes and so on.
Requirement 4-2 'Valuation Information Management'	**Effective systems are needed to manage valuation information** Appropriate valuation information management systems (e.g., a registry or a database) using this part of ISO 19152 LADM should be developed by public authorities for fair and timely valuation of tenure rights in order to promote broader social, economic, environmental, and sustainable development objectives. Input (e.g., legal, locational, physical, environmental characteristics of valuation units, and transaction prices) and output (e.g., value and valuation procedures) data in property valuation processes shall be identified, compiled, recorded, managed and maintained in such systems for effective valuations.
Requirement 4-3 'Linked Public Registries'	**Valuation registry should be linked to the distributed registries needed in the valuation processes** Uniform and accurate valuation of property units requires correct, complete, and up-to-date property data. The fundamental element underpinning property valuation are public registries, which accommodate regular data maintenance and updating of property

	characteristics, ownership details and transaction information. An efficient land administration infrastructure shall link valuation registries to the other distributed public registries such as cadastre, land registry, property price registry, address, and building and dwelling registries.
Requirement 4-4 'Valuation Unit Registration'	**Valuation units should be clearly specified** Effective valuation information management shall support the registration of each valuation unit and their required characteristics. The classification of valuation units and the required characteristics of each valuation unit should be explicitly specified for each valuation process. The required characteristics may be obtained through (1) an existing registry or (2) valuation information registry, itself. A valuation information registry may be developed at the local, regional or national level.
Requirement 4-5 'Valuation Procedure'	**Valuation procedures should be transparently shared** Valuation information management systems compatible with this part of ISO 19152 LADM shall support the determination of value of each valuation unit in accordance with published procedures, where possible based on market values and computer-assisted mass valuation systems.
Requirement 4-6 'Transction Prices and Statistics'	**Efficient information systems for valuation requires to record transaction prices, and to publish indices related to the prices** Efficient land administration system for valuation information management compatible with this part of ISO 19152 LADM shall support the registration of transaction prices and the publication of sales statistics regularly
Requirement 4-7 'Valuation Source Document'	**Reference to valuation source should be supported** All valuation information management systems shall support shall make use of the VM_ValuationSource class to support references to source documents.
Requirement 4-8 'Value Dissemination'	**Property values and processes should be transparently shared with public** Valuation procedures, processes and results shall be transparently shared with general public. Timely and effective dissemination of property values as well as input information related to valuation processes to general public is an essential part of a transparent and efficient valuation system. For this purpose web-map based dissemination is the preferred, and in case of apartments, the 3D web-maps may be preferred.

Table 4. The proposed requirement for LADM Edition II Part 5

Requirement name / Solution	**Requirement Description**
Requirement 5-1 'Core LADM Conformant'	**A land administration system specifically designed for spatial plan information should be based at least on the ISO/TC 211 set of standards** Effective and efficient land administration systems for spatial plan information are compliant with this part of ISO 19152 LADM shall be based on LADM core, namely Party, RRR, BAUnit, SpatialUnit, 2D/3D representations (from 19107), VersionedObject, and all of these are based on source documents.
Requirement 5-2 'Plan Information Dissemination'	**Spatial plan information should be visualised and disseminated** Spatial plan information systems using this part of LADM shall allow open dissemination and clear visualization (2D/3D) plan information.
Requirement 5-3 'Plan Information Monitoring'	**Participatory spatial plan information monitoring should be supported** Spatial plan information systems shall support participatory plan monitoring to detect challenges and evaluate alternative scenarios for intervention making as well as achieving SDGs.
Requirement 5-4 'Plan Unit and	**Spatial plans can be organised with plan units (homogenous, smallest planning unit) in blocks**

Block Relationship'	Spatial plan information compliant with this part of LADM shall organize plan units (plan zones) in plan block, as accepted plans by the relevant authorities for specified time interval.
Requirement 5-5 'Spatial Subfunction'	**All functions and subfunctions should be supported** Effective land administration systems for spatial plan information compliant with this part of ISO 19152 LADM shall provide extensible code list for the spatial (sub)functions of plan units and plan blocks according to national/local regulations.
Requirement 5-6 'Plan Group Hierarchy'	**Spatial planning hierarchy should be supported** Spatial plan information shall support the planning hierarchy (from national to local) via hierarchical plan groups.
Requirement 5-7 'Permit Registration'	**Permit registration should be supported** Efficient and effective spatial plan information management system using this part of ISO 19152 LADM shall support permit registration and relating this to the relevant plan unit.

Figure 1 depicts the package structure of LADM Edition II, designed in a way that meet the requirements. The "Party", "Administrative" and "Spatial Unit" packages are common packages in Part 1 as well as in Part 2. The newly added packages in Part 3 are "Party Group" and "Source Group", in Part 4 the "Valuation information" package is introduced, while in Part 5 the "Spatial plan information" package.

For the common packages, in Part 1 the terms defined in these packages are only introduced, while the detailed description (attributes, data type, relationships, multiplicities, constraints, etc.) of these packages is included in Part 2. The "Generic conceptual model" package, which contains the basic requirements on which each part of Edition II is based, is included in Part 1, while the "Survey and representation" subpackage is specified in Part 2. Part 4 and 5 have been designed as a single package, both based on the definitions in Part 1 and 2. Part 1 and Part 2 together form an application schema as well as Parts 1, 2, 3, 4 and 5.

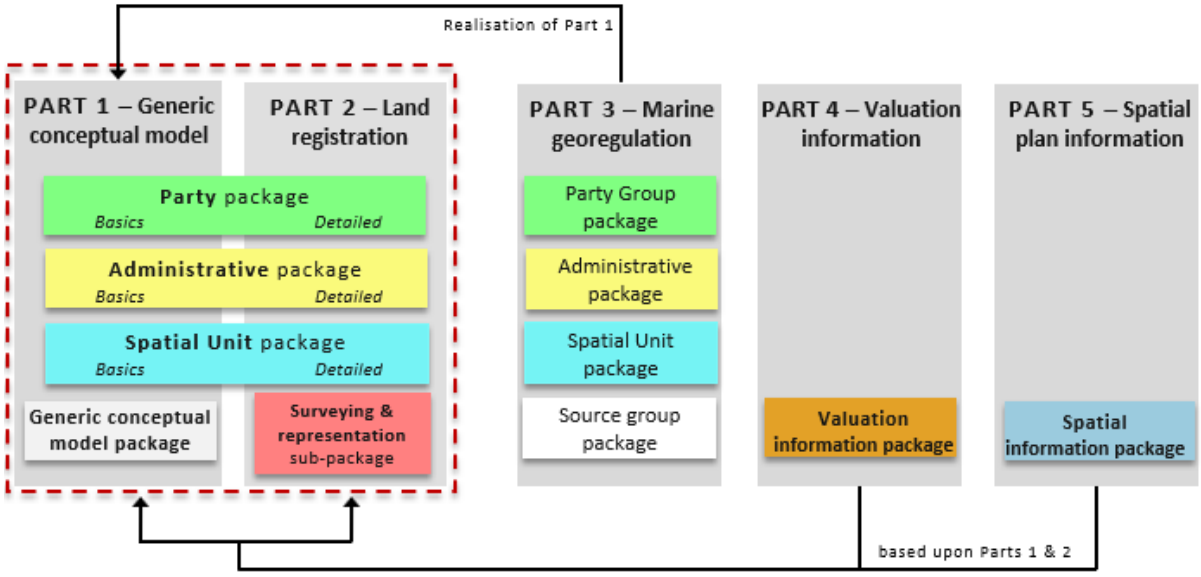


Figure 1. Parts and Packages Design of LADM Edition II

4. CONCLUSION

To conclude, the requirements-based approach provides many benefits:

- stakeholder within the domain can express their needs explicitly,
- standards readers can a very clear and to the point introduction to the domain,
- standards developers have a solid basis to develop and justify their models,
- standards users can use the Abstract Test Suite (ATS), in Annex A of the various parts, to check of their implementation in compliant for that part/package/class of interest.

The operationalization of the LADM Edition I creates opportunities for LA service providers and vendors of Geographic Information Systems (GIS), Document Management Systems (DMS) and Database Management Systems (DBMS) to offer innovative products, services and applications for LA. This in turn enhances the ability of land registry and cadastral organizations to design, develop, implement and maintain their systems with greater efficiency. LADM Edition II extends this capability to marine georegulation, property valuation and spatial planning organizations. In addition, 3D aspects are further supported by new developments (e.g., refined survey model, new types of spatial units, 3D spatial profiles, BIM/IFC as design source). It should be noted that other parts (parts 4 and 5) also support 3D in all aspects.

LADM Edition II adds capabilities to support marine georegulation (not presented in this paper), valuation information, spatial plan information (supporting spatial development) and is closer to implementation (also technical models and processes). This makes LADM Edition II's coverage of land administration/georegulation more complete, which is important if the aim is to harmonize models from these closely related LA sub-domains. The positive votes received on the parts may indicate that the international LA community is satisfied with the proposed refinements and developments.

Part 6 is planned to cover a methodology for developing a LADM country profile, an abstract framework for representing LA workflows (processes), a metamodel for structuring and managing semantically enriched code list values, and support for different encodings (e.g., GML, INTERLIS, RDF, GeoJSON, etc.). In addition, Part 6 is expected to include the OGC API family of standards-compliant recommendations for the development of interoperable LADM schema-based information systems. It will be investigated how well blockchain and ledger technologies can be used to implement the various components of LA systems. Furthermore, the relationships between the LADM and the instruction guidelines for property measurement, such as the International Property Measurement Standards (IPMS) and the International Land Measurement Standard (ILMS), is planned to be included in Part 6.

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BIOGRAPHICAL NOTES

Abdullah Kara holds a Ph.D. degree from Yıldız Technical University (YTU) with a thesis on the extension of Land Administration Domain Model (LADM) with valuation information, which is used as a basis for the development of LADM Part 4 - Valuation information. He is currently working as a post-doctoral researcher at the GIS Technology Section, Delft University of Technology. He has been actively involved in FIG working groups.

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3D property formation in complex infrastructure- and building projects - Exemplified by the Slussen project in Stockholm

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Key words: 3D real property, property formation, 3D models, registration, Sweden.

SUMMARY

This paper describes the use of 3D real property formation at a major construction site in Stockholm, Sweden, project Slussen.

Real property formation with complex 3D volumes and numerous real properties and associated rights, restrictions and responsibilities (RRRs) has to be shown with the real properties and RRRs in relation to each other. The present legal solutions and documentation thereof are based on analogue documentation (digitalised to pdf) and cannot be attached as e.g. dwg files. Architects and other professionals do not normally have access to the 3D real property boundaries in their 3D building models from the beginning of a project and the exact locations of boundaries are agreed upon during the formation process to achieve as usable solutions as possible.

The aim of this paper is to describe the 3D property formation process when involving complex solutions securing RRRs to solve legal and planning challenges on different levels of detail. The paper focuses on the cadastral real property formation procedures using 3D property formation for constructions above and underground, as well as how they are registered in the national real property register. The paper illustrates a complex 3D property solution and adds to the understanding of the challenges of registration and visualisation of Swedish 3D real property in Stockholm, focusing on legal as well as technical experiences.

This research is a document study based on an analysis of the property formation and planning documentation and processes of a cadastral procedure conducted in the Slussen project, as well as associated documentation from other agencies, and by interviewing key persons involved in the project. The paper illustrates the need for a national cadastral index map in three dimensions to be used in the formal real property formation procedures, to achieve a comprehensible and correct representation and visualisation of 3D real properties and RRRs in Sweden.

The results can be used as input in coming property formations of a similar kind, as well as a component for the development of a national three-dimensional cadastral index map. Furthermore, the results can be an input to capacity building for the future use of 3D models as part of the formal cadastral property formation procedure.

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1. INTRODUCTION

Three-dimensional (3D) property rights have been successfully used for a long time in a number of countries, see e.g. Oosterom et al. (2018), but in Sweden, the formation of 3D real property is a rather new possibility. It was introduced in the legislation in 2004, followed by legislation allowing apartment ownership in 2009 (SFS 1970:944).

1.1 Background

A demand for the formation of 3D properties had existed before its introduction in Sweden for quite some time, to create the possibility of dividing the ownership of space or buildings above or below ground. Among the needs for 3D property that were expressed in the investigations preceding the legislation (Proposition 2002/03:116) were mentioned separating the ownership in large complex projects with a need for extensive funding, e.g. for infrastructure purposes.

The formation of 3D property has so far not been as high as was expected when introducing the legislation, but the use of it seems to be increasing. This also creates a larger need for finding sustainable solutions for three-dimensional registration and visualisation of 3D property units and connected rights, restrictions and responsibilities (RRRs). This can in particular be the case for more complex projects. This paper describes the use of 3D real property formation at a major construction site in Stockholm, Sweden. Project Slussen is an initiative to demolish the old existing lock in the historic waterway through the city, which is connected today to an ineffective traffic solution in central Stockholm, and replace it with a modern boat lock and a new traffic solution. The Slussen lock has since centuries formed an important waterway through the Swedish capital regulating the boat traffic and water level between the Baltic Sea and Lake Mälaren. This construction project also includes the formation of 3D real property as well as RRRs. Stockholm municipality is responsible for real property formation within their boundaries, a municipal responsibility that is allowed in currently 40 Swedish municipalities, whereas property formation is the responsibility of Lantmäteriet, the Swedish Mapping, Cadastral and Land Registration Authority, in the remaining parts of Sweden.

Real property formation with complex 3D volumes and numerous real properties and associated RRRs are shown with the real properties and RRRs in relation to each other. The present legal solutions and documentation thereof are based on analogue documentation

(digitalised to pdf) and cannot be attached as e.g. dwg files. Architects and other professionals do not normally have access to the 3D real property boundaries in their 3D building models from the beginning of a project and the exact location of boundaries are agreed upon during the formation process to achieve as usable solutions as possible.

1.2 Problem description

According to Swedish legislation and recommendations, cadastral boundaries for 3D property units shall be described in relation to the physical construction surrounding the property unit and the 3D volume shall enclose a building or other construction. The legislation is based on the procedure that in normal cases, first a legal 2D-property is created, thereafter building permission is obtained and finally the 3D property is created. This procedure is however not possible to use when a detailed plan vertically separates public space and development district. In such cases, it is required to separate the procedures for public space and development districts before being able to obtain a building permit.

The result is that the separation between public space and development districts has to be made before acquiring the building permit and constructing the building. In order to secure that it is possible to obtain a building permit on the property and thereby ensure its suitability, normally a parallel process with building permit and property formation is created in such cases. The parallel process is needed for both the cadastral surveyor and the building permit official to be able to co-operate in understanding and interpreting the situation, since the decisions are co-dependent.

The cadastral surveyor in these property formation processes needs to interpret the applicable regulations in the detailed plan to make sure, for example, that the border between public space and development districts complies with the regulations. This applies both horizontally and vertically when 3D property units are created. The detailed plan regulations include a scope of interpretation, but should to a high degree show a clear picture of boundaries between different permitted uses.

A challenge for the cadastral surveyor is to assure that it is clearly described where the boundaries of the 3D property unit is located as well as the extent of other RRRs, though without using a 3D model as part of the cadastral decision, since this at the moment only can consist of 2D documents. This creates challenges to visualise without being able to use for example a 3D model of the 3D property unit. Also, when recording the result of the property formation into the real property register, it can, as of today, only be displayed in a 2D map and with limited information about height spread, since there is not a 3D cadastral index map available.

1.3 Aim

The aim of this paper is to describe the 3D property formation process when involving complex solutions securing RRRs to solve legal and planning challenges on different levels of detail. The paper focuses on the cadastral real property formation procedures using 3D property formation for constructions above and underground, as well as how they are registered in the national real property register. The paper illustrates a complex 3D property

solution and adds to the understanding of the challenges of registration and visualisation of Swedish 3D real property, focussing on legal as well as technical experiences.

1.4 Method

This paper is based on the study of project documents from the cadastral dossier from creation of the property unit subject for the case study (cadastral map, descriptive texts of the cadastral decision as well as describing pictures from 3D models etc.), including material from construction companies submitted to Stockholm municipality as part of the Slussen project. In addition to this, interviews were made with experts and others involved in the property formation and creation of associated RRRs, as well as the visualisation thereof. The project was conducted with the responsible cadastral surveyor in charge of the property formation and the GIS expert responsible for the digital models and drawings used in the formation process. The research investigated how different legal documents and technical documentation for the property formation were created, how new cadastral boundaries were formed and how this was illustrated in an optimal way in 3D drawings/models.

The process for 3D real property formation described in this paper is general for Sweden, but the presented project is of a particularly complex nature and thus involves parts and aspects that are not always relevant in all cases of 3D property formation.

1.5 Previous research

National and international research has focused on more theoretical issues and (manual) digitization of geographic information, but has not addressed to a large extent how increased automation and use of 3D models etc. in decision-making can contribute to streamlining the community building process. In international research over the past two decades, there has been a focus on the implementation of conceptual technical solutions as part of the development of registration and visualisation of 3D properties. Technical solutions investigated in the international research primarily consist of conceptual models for the visualisation of 3D properties developed specifically for implementation in an intended legal domain. A lack of practical examples of implementation was already described several years ago in connection with a lack of focus on the legal aspects within the research area e.g. (Ho et al. (2013). This is consistent with bibliographic analyses of publications in the research area, published in 2013 and 2021 (Paulsson and Paasch, 2013; Paasch and Paulsson, 2021).

2. SWEDISH 3D PROPERTY RIGHTS

The Swedish traditional 2D property unit is delimited horizontally with x and y coordinates. In theory, it contains a volume extending upwards into the sky and down to the centre of the earth, but in practice limited by how much the property owner can use upwards and downwards from the ground level. In densely built areas where there are different activities competing for the same space within the volume, different actors can gain access through different kinds of rights, or through 3D property formation where the ownership of these different activities can be separated. A three–dimensional property is formed in the same way as a traditional 2D property and is regulated by the same rules, although additional rules for

this type of property have been included in the existing real property legislation. See Larsson et al. (2018; 2020) and Seipel et al. (2020) for an introduction to the Swedish 3D real property formation process.

The 3D property is delimited both horizontally and vertically. The property is intended to accommodate a building or other facility, or part thereof. Unlike many other jurisdictions (see e.g. Paulsson, 2007), Swedish legislation has not included regulation on the location or visualisation of the cadastral boundaries in relation to the physical building construction that has to surround the 3D property unit and make its boundaries visual. It is stipulated that the boundaries shall follow the construction, but according to the cadastral recommendations, a small volume of air can be included in the property unit in order to include e.g. protruding construction details, although no additional space is allowed for future building rights. Despite the requirement for the property boundary following a construction, it is possible to form a 3D property for a future construction with the condition that it will be developed within a fixed amount of time set in the property formation decision.

Necessary rights needed for the proper use of the 3D property unit must be legally secured in the property formation. Ownership apartments (condominium) is a special form of 3D property intended for a single dwelling and has additional regulations for its formation, such as that it can only be formed in new buildings or in existing buildings which have contained no residential housing for the past eight years.

The process to form a 3D property unit starts with an application to the cadastral authority who will check the application if it meets the requirements in the legislation, planning regulations, building permission, etc. As mentioned, the legislation does not define the location of the property boundaries for the 3D property units, which means that this will be discussed between the cadastral surveyor and the applicant and decided which is the most suitable solution for the location. The location of the boundaries and their relation to adjacent property units will be described in writing, in addition to shown on maps and drawings. Also other boundaries for RRRs, e.g. easements and joint facilities, are described in the same way. The cadastral documents that are submitted to the authority or created in the property formation process are mostly in paper format or frozen digital images. Examples of such documents are previous property formation decisions, planning regulations and building permissions. CAD drawings containing the 3D real property boundaries may also be used in the process, created and provided by the developer/entrepreneur. Such drawings will however not be archived in the national real property register, although they may be archived for future use by the cadastral authority where no standardised solutions exist but are done differently depending on authority.

Real property formation with complex 3D volumes and numerous real properties and associated RRRs has to be shown with the real properties and RRRs in relation to each other. The present legal solutions and documentation thereof are based on analogue documentation (digitalised to pdf) and cannot be attached as e.g. dwg files. Architects and other professionals do not normally have access to the 3D real property boundaries in their 3D building models from the beginning of a project and the exact locations of boundaries are agreed upon during

the formation process to achieve as usable solutions as possible. The same type of documents and cadastral procedures are used for all types of 3D property formation, although the case presented in this paper is more complex than most other cases of 3D property formation and thus includes more complications and aspects to consider.

The study presented in this paper is a continuation of and an addition to previous research in this field that has been carried out by, among others, the authors of this paper. Research in Sweden within 3D properties has been going on for more than two decades, but many research results have not yet been implemented in legislation or included in development projects by authorities and other actors. However, research has been conducted in several sub-areas relating to 3D real estate objects, such as comparative studies of ownership of 3D real property in selected national legislations, e.g. Paulsson (2007) and Çağdaş et al. (2020) and the use of 3D property formation in the construction of bridges and other infrastructure facilities (Karabin et al., 2020), as well as analyses of trends in the 3D property research field (Paulsson and Paasch, 2013; Paasch and Paulsson, 2021). In recent years, 3D models have been the focus of some research, e.g. regarding the use of BIM in connection with 3D property formation and management of property information as well as the use of 3D city models for digital register maps (Sun et al., 2021; Sun et al., 2023). An ongoing project in the City of Stockholm works with visualisation of existing 3D spaces in the municipality.

In addition, several research projects have been conducted within the Smart Built Environment, e.g. around BIM as information support for 3D real property formation (Andreé et al., 2018),. Examples of this are which information is only available in analog form today and which information must be digitised, possibly retrieved from other sources to be used in administrative proceedings, and that guidelines must be drawn up for archiving geodata and property information produced in connection with the handling of the proceedings; BIM data for accounting of 3D real estate formation, as well as issues linked to infrastructure data/projects; overview information such as small-scale geodata and overview plans, as well as perceived legal barriers to a digital community building process have also been investigated. See e.g. (Andreé, et al (2019; 2020). Other relevant projects deal with Swedish 3D property boundaries (Larsson et al., 2020), visualisation of 3D property boundaries (Seipel et al., 2020).

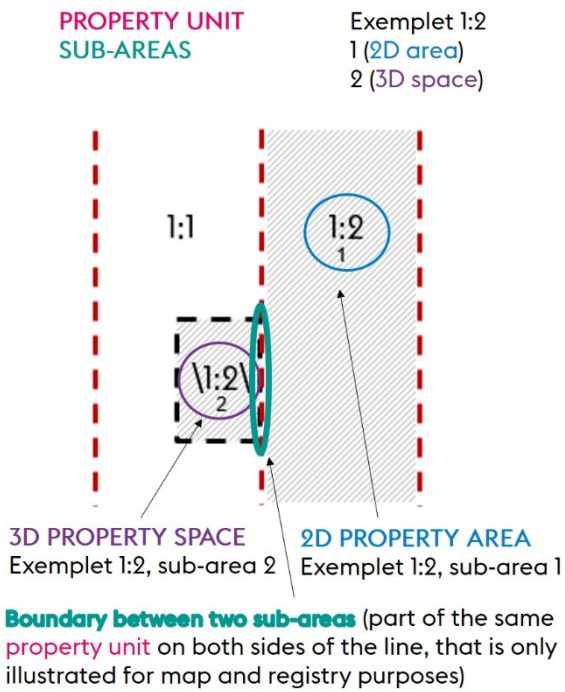


Figure 1. Illustration of representation of 2D in relation to 3D property in the real property register and cadastral dossiers

3. CASE STUDY

For all 3D property formation there is a need for reliable and correct presentation of the property boundaries and property rights in the property formation decisions as well as in the cadastral index map and the real property registry. The Slussen area in Stockholm, that is used for this case study, is more complex in many ways than the average 3D property formation in Sweden, however the findings and experiences can be used for all cases of 3D property formation.

3.1 Background of the area

The Slussen area in Stockholm is named after its historically main function, a water lock ("sluss" in Swedish) between lake Mälaren and the Baltic Sea, and Slussen translates thus to "the Water Lock". The infrastructure surrounding the water lock has been rebuilt and modernised several times since the first known water lock was completed in 1642. From older maps we can determine that the strait between the islands of Gamla Stan (Old Town) and Södermalm, two parts of Stockholm city, has been used as a passage for longer than that. The water lock has since 1642 been rebuilt once every century (years 1755, 1850 and 1935), due to wear and tear as well as changes in water levels and other natural changes. This has also impacted the area around the water lock.

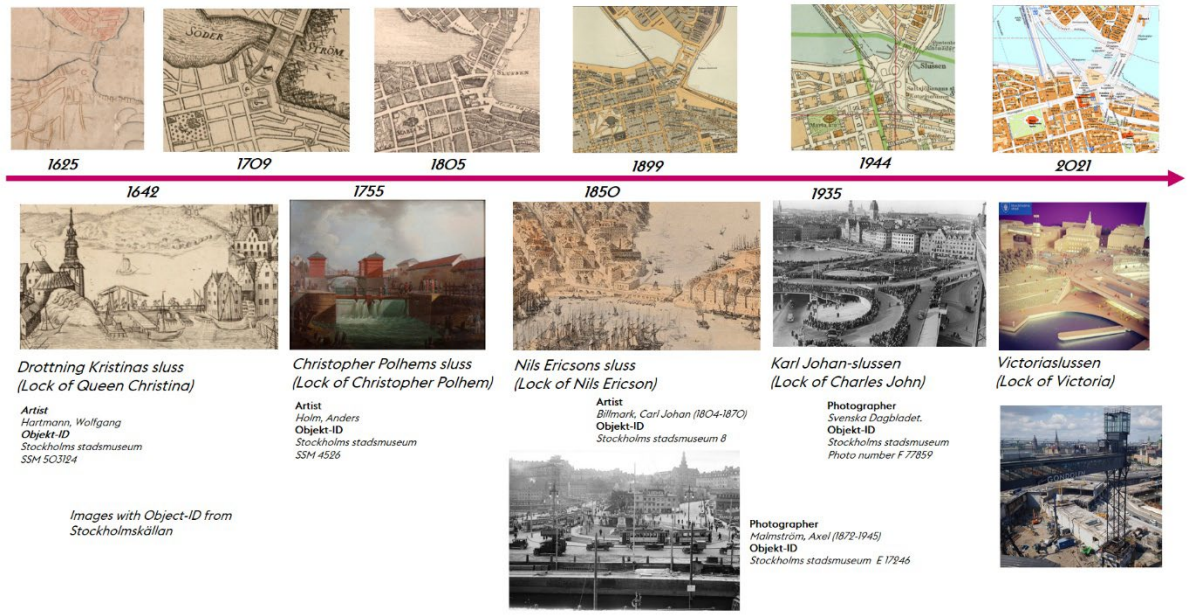


Figure 2. History of water locks in the Slussen area https://stockholmskallan.stockholm.se/

The Slussen water lock was last rebuilt in the 1930s, almost a hundred years ago. The construction was mainly made out of concrete, and after several decades the constructions started to deteriorate, and another reconstruction was thus needed. The new water lock, currently under construction, is called Victoriaslussen (Water Lock of Victoria), named after the current Crown Princess Victoria of Sweden.

3.2 Current development in the Slussen area

A new detailed development plan was produced for the Slussen area prior to the ongoing reconstruction and became legally binding in December 2011. However, the planning process for a new water lock facility began decades earlier with an idea competition arranged in the early 1990s. Around the turn of the millennium, the work resumed and in 2004, an architectural competition was announced where a winner was also named.

The detailed development plan makes possible for a full reconstruction and new locations and stretches of infrastructure, as well as new structures for development districts and connected building rights. There are many different types of infrastructure located in the area; two subway lines intersect, as well as a third line about to be built, there is a large bus station and a local train line end station, ferry lines and also cars, bikes and pedestrians, both locals and tourists. The area consists of a variety of branches of activity, such as housing, offices, hotels, restaurants and commercial areas.

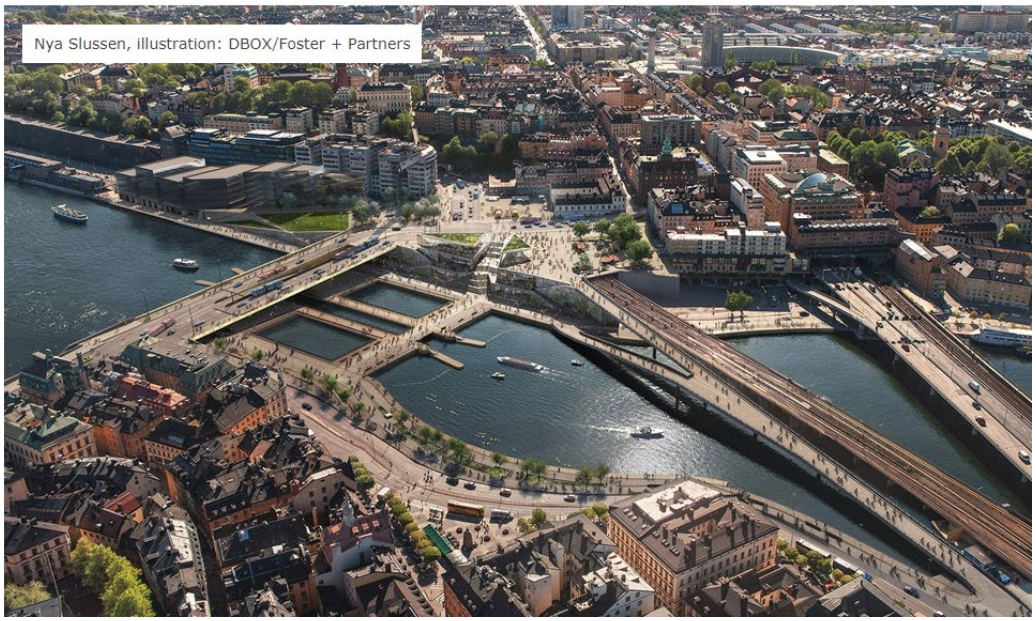


Figure 3. Vision picture of the Slussen area when completed https://vaxer.stockholm/projekt/slussen/

The detailed development plan is a 2D plan describing a lot of regulations in 3D, i.e. public spaces on top of building rights for stores underground. Within the property formation and building permit processes there is a need to interpret where the boundary between public and private areas is located within the detailed development plan, both horizontally and vertically. The full reconstruction of the water lock Slussen as well as connecting infrastructure and a lot of the new buildings are estimated to be finished in 2027.

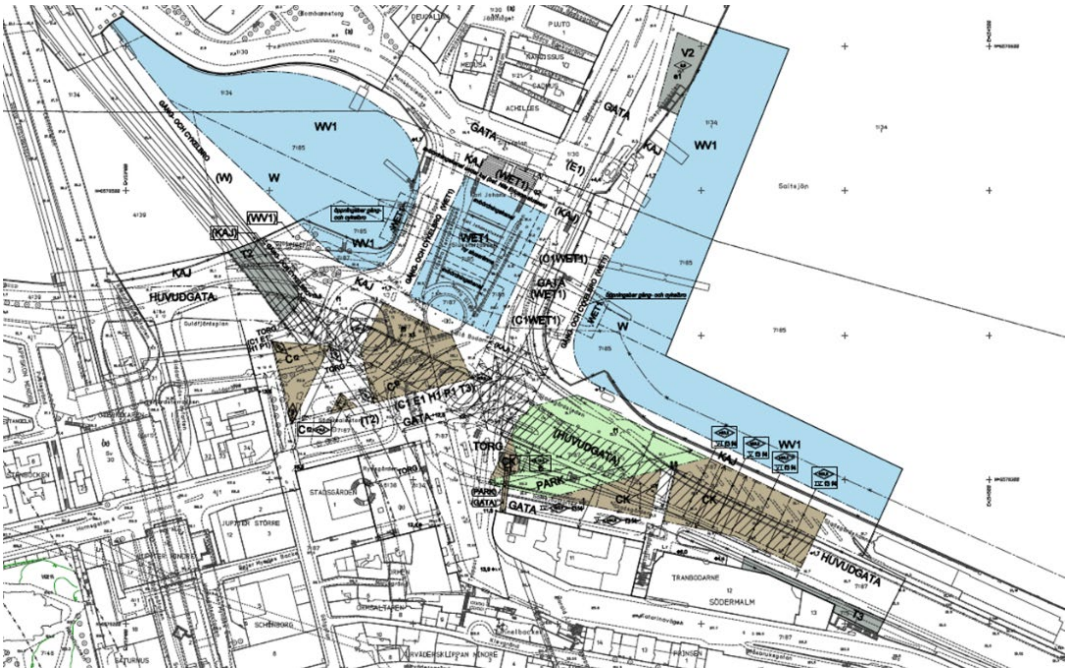


Figure 4. Extract from the current detailed development plan of Slussen area (P2005-08976). Source: Bygg- och plantjänsten, City of Stockholm https://etjanst.stockholm.se/Byggochplantjansten/gallande-planer/sok-via-karta

The changes in the buildings and facilities in the Slussen area also have influenced the necessary and suitable division of the real properties and associated RRRs, both in 2D and 3D. The first larger cadastral procedure in the project was carried out during 2021-2022 and constituted a very complex 3D property formation combining a number of different interests. The main property unit subject for re-formation, called "Södre Torn 1", is located next to as well as under and above public spaces (street, plaza, quay, etc.), subway facilities and thoroughfare car tunnel (another 3D property unit that was created at the same time). The property unit "Södre Torn 1" will at a later stage be connected to another 3D property unit for shopping facilities that will be created. A multitude of RRRs are needed to ensure the suitability of these 3D properties.

3.3 Property formation in the Slussen area

The property formation is, as described above, part of the implementation of the reconstruction of this part of central Stockholm. Involved parties in the process, such as developers and the municipality (who owns the current property units), have produced 3D models for the facilities as part of their work that in detail show planned buildings, infrastructure, positions of pipes etc. However, these 3D models do not include planned or desired 3D boundary lines. In Sweden, as of current conditions, 3D models cannot be used as part of the real property decision. The property formation dossier consists either of paper documents or of pdf-files (not 3D pdf). That is why the content of the cadastral plans produced as a basis for the cadastral work has been extracted from the 3D digital models and used in 2D drawings, in addition to creating 3D cadastral volumes showing the approximate location and extent of 3D real property volumes, which are later used in 2D form (pictures of 3D-volumes from different directions). Architects and construction companies do not have boundary lines in their 3D-models from the beginning, and the actual location of the boundaries are decided upon during the cadastral formation process to create suitable real properties and associated RRRs.

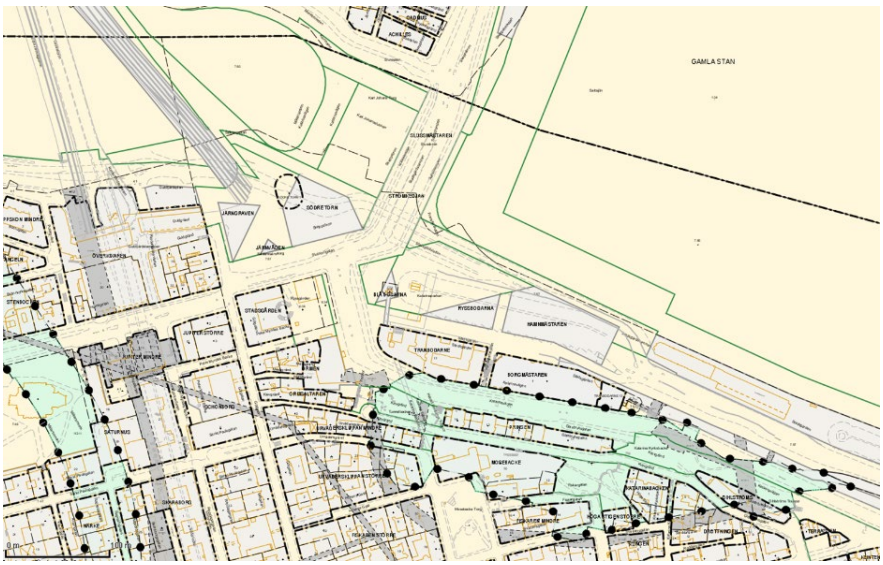


Figure 5. Cadastral index map of the Slussen area before the transformation of property unit Södre Torn 1. Adapted from Larsson (2021)

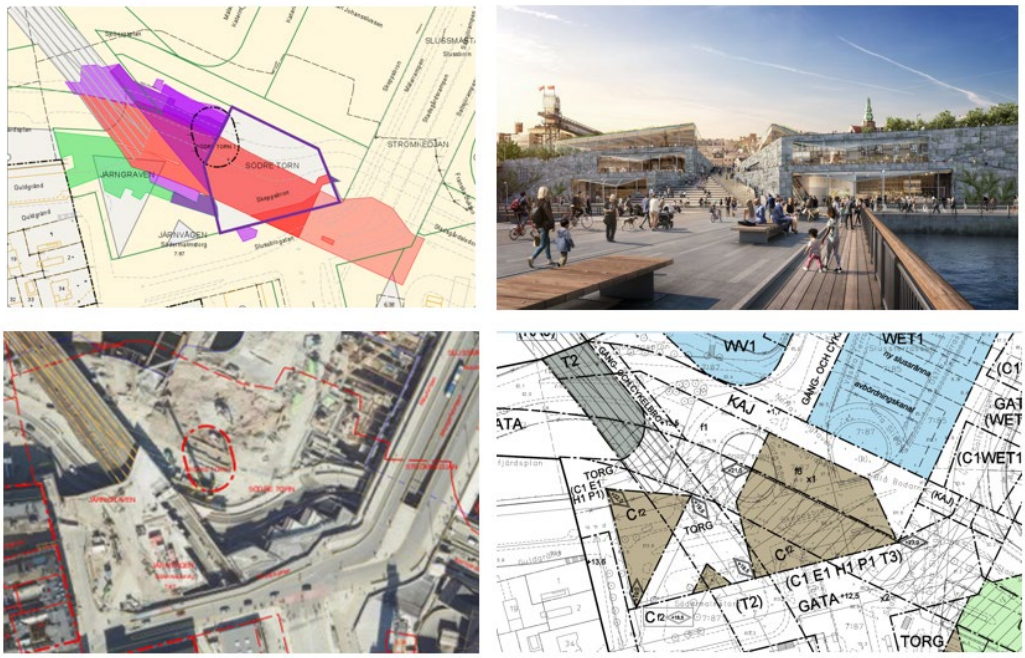


Figure 6. Top left: Requested new RRRs for Södra Torn 1 merged to the cadastral index map for reference, as part of the property formation process. Top right: vision picture of the area around Södra Torn 1. Bottom left: Orthophoto of the Slussen area before the transformation of property unit Södra Torn 1. Bottom right: Regulations in the detailed plan of the area. Adapted from Larsson (2021)

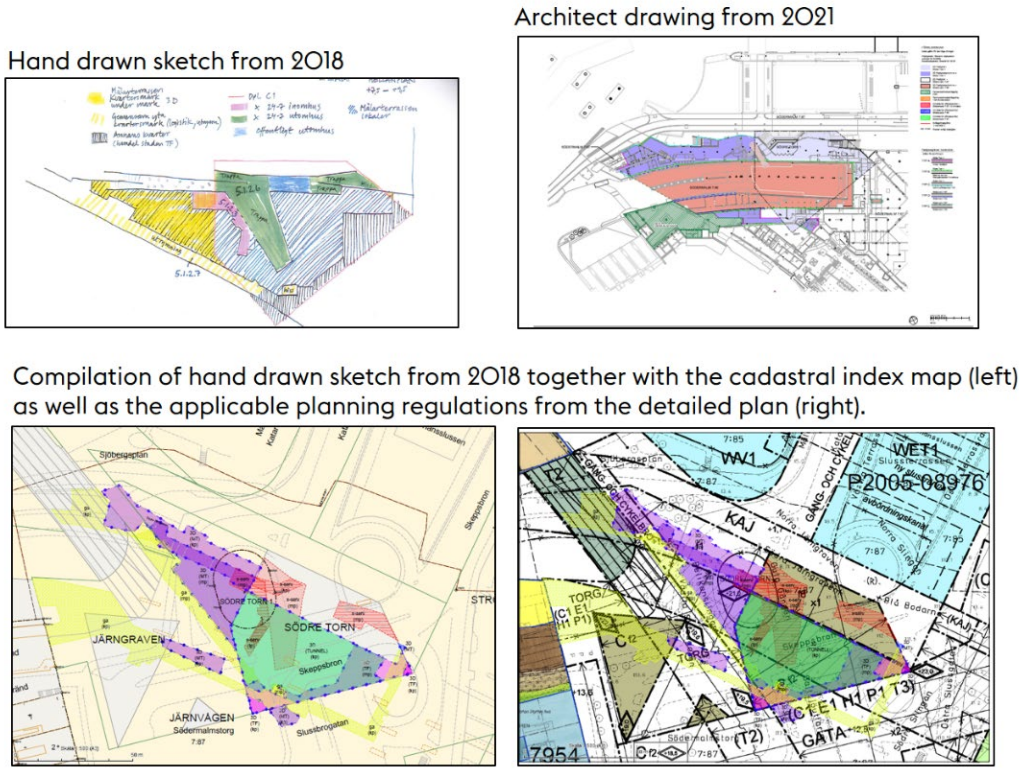


Figure 7. Material used during the property formation process. Adapted from Larsson (2021)

To be able to visualise the overview distribution of and relationships between different 3D property units, a simplified 3D model was created. The detailed CAD plan drawings of different levels were used as reference, then each floor/layer was elevated up to the next available level of plan drawing. From this, volumes of each 3D property unit was created, and the separate property units were given different colours. These volumes simply gave a rough estimate of the spread of each floor, without showing any details. The volumes created were combined with a BIM model of the planned building that was provided by the property owner and property developer. In the 3D model created it was possible to show or hide any property unit in order to view the desired spread or relationship. The viewing point could be shifted to the desired position to be able to distinguish details. Screenshots of the 3D model were used as part of the property formation decisions of Södre Torn 1. In addition a 3D pdf was provided by the property developer. The 3D pdf had more detail than the 3D model created from CAD plan drawings, but still only shows an estimate of the spread, not the exact boundaries.

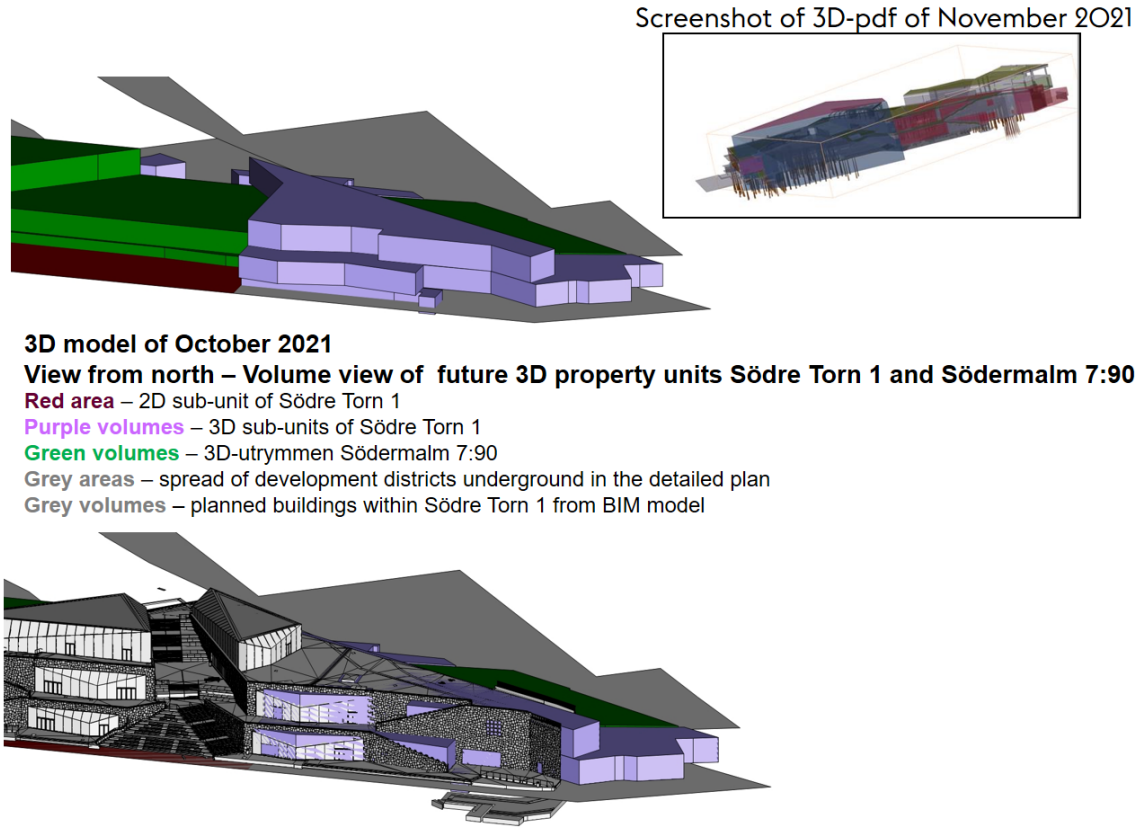


Figure 8. Left: Early versions of 3D volumes created within the property formation process and combined with BIM model of planned buildings acquired from the property owner and developer, to use for understanding and interpretation of suggested property boundaries etc. Right: Screenshot of 3D pdf, later used as part of the property formation decisions. Adapted from Larsson (2021)

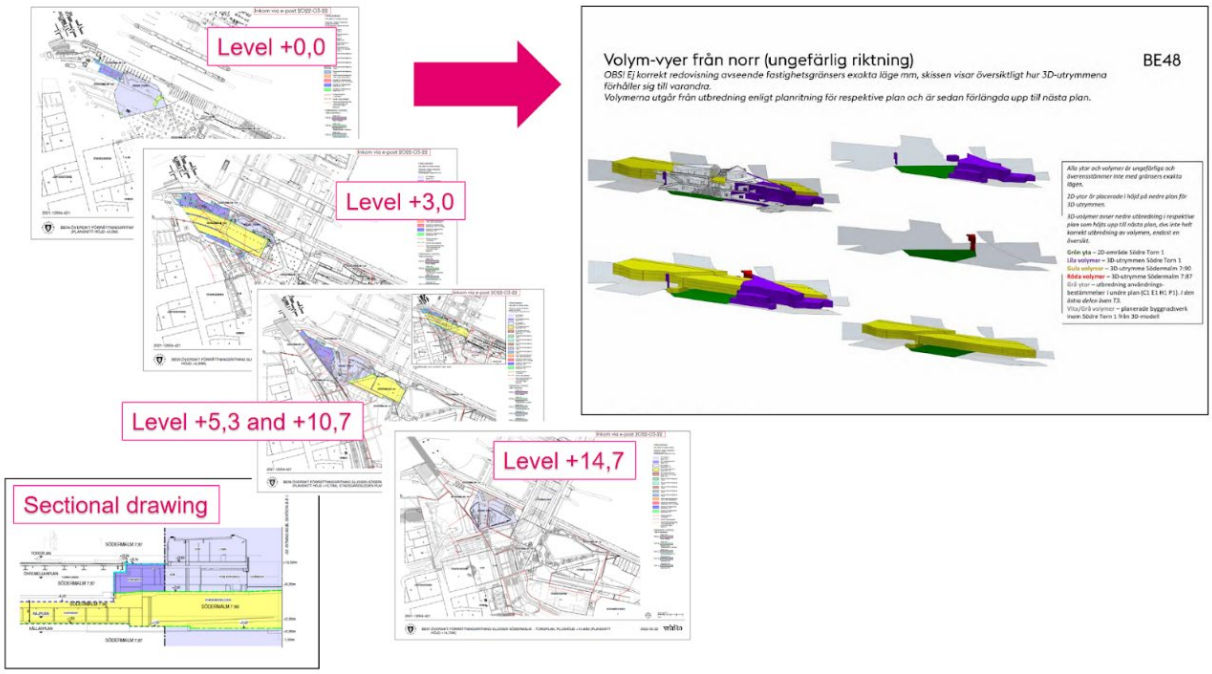


Figure 9. Extract from property formation dossier. Example of visualisation of 3D models of 3D property unit Södre Torn 1. From the property formation dossier of Södre Torn 1, 0180K-2021-12004. City of Stockholm

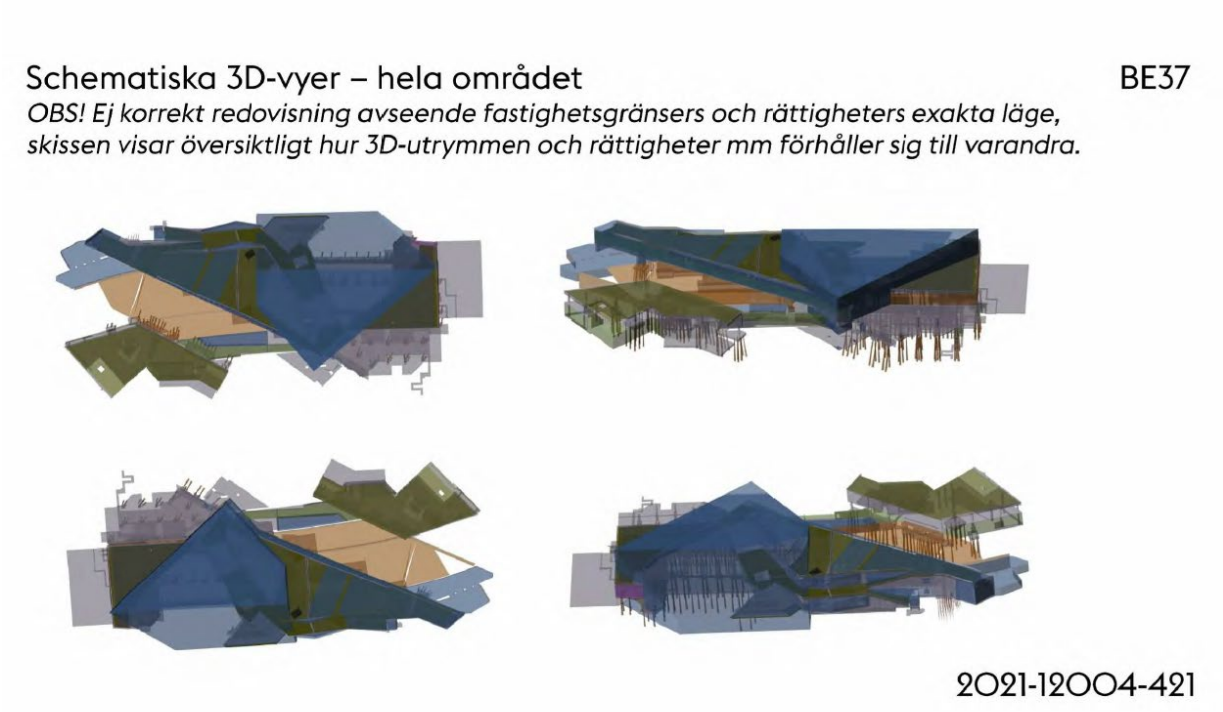


Figure 10. Extract from property formation dossier. Example of screenshots from a 3D pdf showing 3D property unit Södre Torn 1 as well as surrounding property units in a schematic manner. From the property formation dossier of Södre Torn 1, 0180K-2021-12004. City of Stockholm

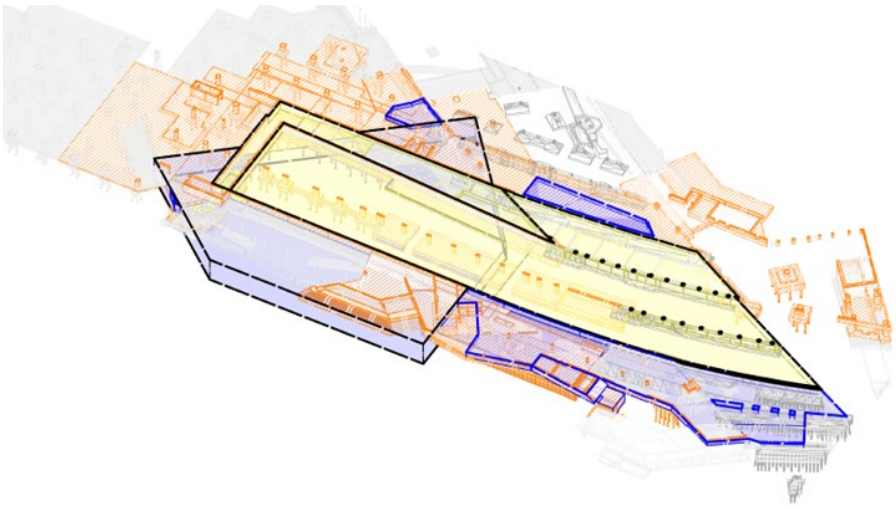


Figure 11. Extract from property formation dossier. Example of screenshots from a 3D model delivered by the property owner and property developer, showing 3D property unit Södre Torn 1 as well as surrounding property units and RRRs in a schematic manner. From the property formation dossier of Södre Torn 1, 0180K-2021-12004. City of Stockholm.

The property formation dossier of 3D property unit Södre Torn 1 consists of, among other documents, four cadastral maps, 26 pages of verbal description of the property formation, 100 pages of drawings, over 30 pages of compilation of planning provisions and nine pages of protocol including a summary of the property formation as well as the property formation decisions. These documents need to be read and interpreted together to be able to determine the exact location of a certain boundary line or other detail regarding the concerned RRRs.

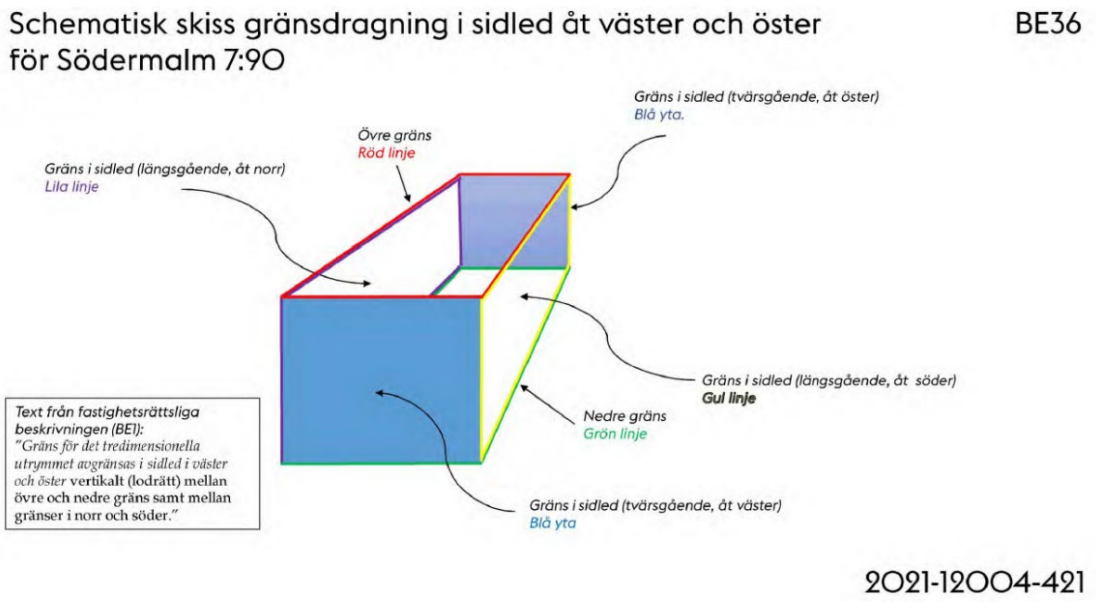


Figure 12. Extract from property formation dossier. Schematic drawing describing boundaries of 3D property unit Södermalm 7:90 at the entrances of a road tunnel. From the property formation dossier of Södre Torn 1, 0180K-2021-12004. City of Stockholm

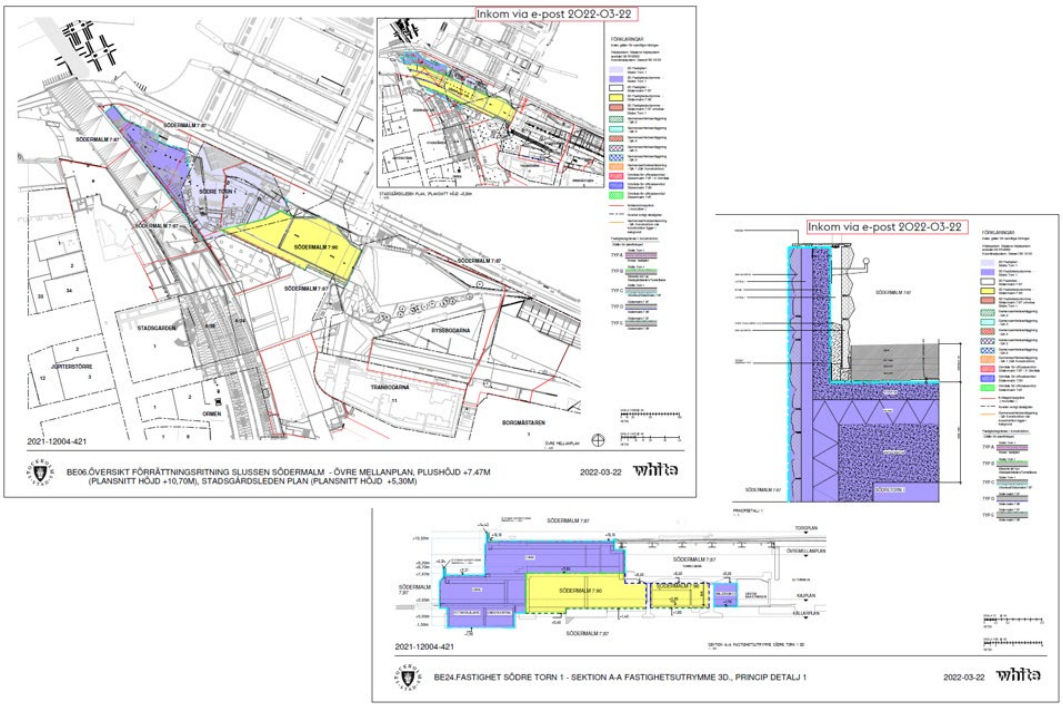
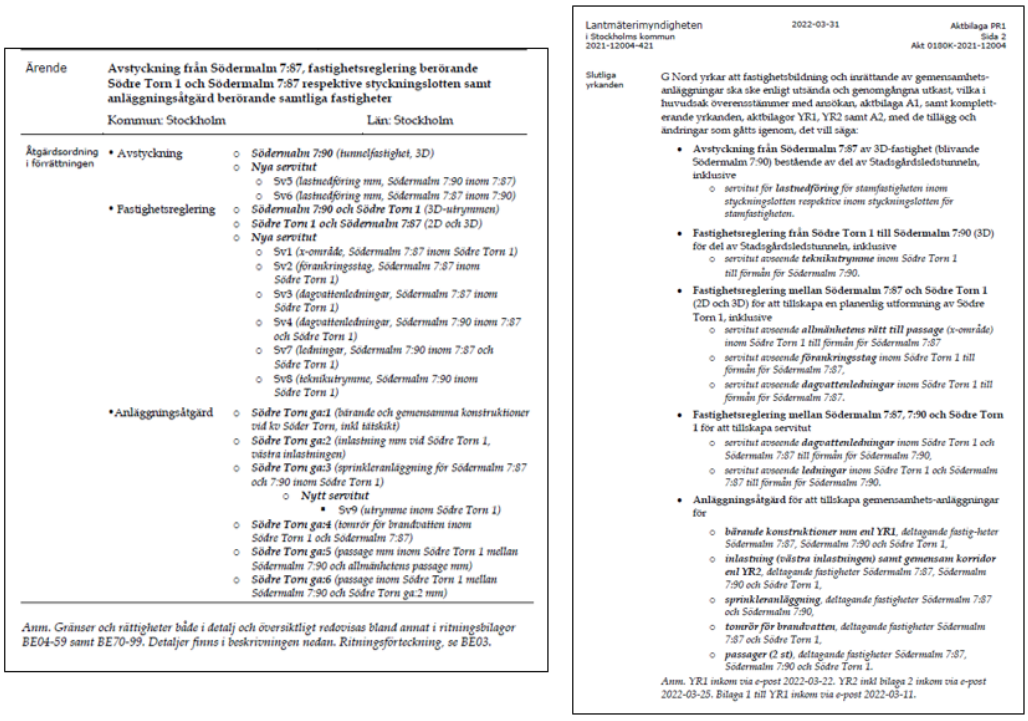


Figure 13. Extract from property formation dossier. Drawings describing boundaries of 2D and 3D property units. From the property formation dossier of Södre Torn 1, 0180K-2021-12004. City of Stockholm



Ärende

Avstyckning från Södermalm 7:87, fastighetsreglering berörande Södre Torn 1 och Södermalm 7:87 respektive styckningslotten samt anläggningsåtgärd berörande samtliga fastigheter

Kommun: Stockholm Län: Stockholm

Åtgärdsordning i förrättningen

- Avstyckning
  - *Södermalm 7:90 (tunnelfastighet, 3D)*
  - *Nya servitut*
    - Sv5 (lastnedföring mm, Södermalm 7:90 inom 7:87)
    - Sv6 (lastnedföring mm, Södermalm 7:87 inom 7:90)
- Fastighetsreglering
  - *Södermalm 7:90 och Södre Torn 1 (3D-utrymmen)*
  - *Södre Torn 1 och Södermalm 7:87 (2D och 3D)*
  - *Nya servitut*
    - Sv1 (x-område, Södermalm 7:87 inom Södre Torn 1)
    - Sv2 (förankringsstag, Södermalm 7:87 inom Södre Torn 1)
    - Sv3 (dagvattenledningar, Södermalm 7:87 inom Södre Torn 1)
    - Sv4 (dagvattenledningar, Södermalm 7:90 inom 7:87 och Södre Torn 1)
    - Sv7 (ledningar, Södermalm 7:90 inom 7:87 och Södre Torn 1)
    - Sv8 (teknikutrymme, Södermalm 7:90 inom Södre Torn 1)
- Anläggningsåtgärd
  - *Södre Torn ga:1 (bärande och gemensamma konstruktioner vid kv Söder Torn, inkl tätskikt)*
  - *Södre Torn ga:2 (inlastning mm vid Södre Torn 1, västra inlastningen)*
  - *Södre Torn ga:3 (sprinkleranläggning för Södermalm 7:87 och 7:90 inom Södre Torn 1)*
    - *Nytt servitut*
      - Sv9 (utrymme inom Södre Torn 1)
  - *Södre Torn ga:4 (tomrör för brandvatten inom Södre Torn 1 och Södermalm 7:87)*
  - *Södre Torn ga:5 (passage mm inom Södre Torn 1 mellan Södermalm 7:90 och allmänhetens passage mm)*
  - *Södre Torn ga:6 (passage inom Södre Torn 1 mellan Södermalm 7:90 och Södre Torn ga:2 mm)*

Anm. Gränser och rättigheter både i detalj och översiktligt redovisas bland annat i ritningsbilagor BE04-59 samt BE70-99. Detaljer finns i beskrivningen nedan. Ritningsförteckning, se BE03.

Lantmäterimyndigheten i Stockholms kommun 2021-12004-421 — 2022-03-31 — Aktbilaga PR1, Sida 2, Akt 0180K-2021-12004

Slutliga yrkanden

G Nord yrkar att fastighetsbildning och inrättande av gemensamhetsanläggningar ska ske enligt utsända och genomgångna utkast, vilka i huvudsak överensstämmer med ansökan, aktbilaga A1, samt kompletterande yrkanden, aktbilagor YR1, YR2 samt A2, med de tillägg och ändringar som gätts igenom, det vill säga:

- **Avstyckning från Södermalm 7:87** av 3D-fastighet (blivande Södermalm 7:90) bestående av del av Stadsgårdsledstunneln, inklusive
  - *servitut för* ***lastnedföring*** *för stamfastigheten inom stycknings-lotten respektive inom styckningslotten för stamfastigheten.*
- **Fastighetsreglering från Södre Torn 1 till Södermalm 7:90** (3D) för del av Stadsgårdsledstunneln, inklusive
  - *servitut avseende* ***teknikutrymme*** *inom Södre Torn 1 till förmån för Södermalm 7:90.*
- **Fastighetsreglering mellan Södermalm 7:87 och Södre Torn 1** (2D och 3D) för att tillskapa en planenlig utformning av Södre Torn 1, inklusive
  - *servitut avseende* ***allmänhetens rätt till passage*** *(x-område) inom Södre Torn 1 till förmån för Södermalm 7:87*
  - *servitut avseende* ***förankringsstag*** *inom Södre Torn 1 till förmån för Södermalm 7:87,*
  - *servitut avseende* ***dagvattenledningar*** *inom Södre Torn 1 till förmån för Södermalm 7:87.*
- **Fastighetsreglering mellan Södermalm 7:87, 7:90 och Södre Torn 1** för att tillskapa servitut
  - *servitut avseende* ***dagvattenledningar*** *inom Södre Torn 1 och Södermalm 7:87 till förmån för Södermalm 7:90,*
  - *servitut avseende* ***ledningar*** *inom Södre Torn 1 och Södermalm 7:87 till förmån för Södermalm 7:90.*
- **Anläggningsåtgärd** för att tillskapa gemensamhets-anläggningar för
  - ***bärande konstruktioner mm enl YR1****, deltagande fastig-heter Södermalm 7:87, Södermalm 7:90 och Södre Torn 1,*
  - ***inlastning (västra inlastningen) samt gemensam korridor enl YR2****, deltagande fastigheter Södermalm 7:87, Södermalm 7:90 och Södre Torn 1,*
  - ***sprinkleranläggning****, deltagande fastigheter Södermalm 7:87 och Södermalm 7:90,*
  - ***tomrör för brandvatten****, deltagande fastigheter Södermalm 7:87 och Södre Torn 1,*
  - ***passager (2 st)****, deltagande fastigheter Södermalm 7:87, Södermalm 7:90 och Södre Torn 1.*

Anm. YR1 inkom via e-post 2022-03-22. YR2 inkl bilaga 2 inkom via e-post 2022-03-25. Bilaga 1 till YR1 inkom via e-post 2022-03-11.

Figure 14. Extract from property formation dossier. Left: Verbal description of actions in the property formation decision. Right: One page of the protocol summarising the applicants claims for desired design of the property formation. From the property formation dossier of Södre Torn 1, 0180K-2021-12004. City of Stockholm

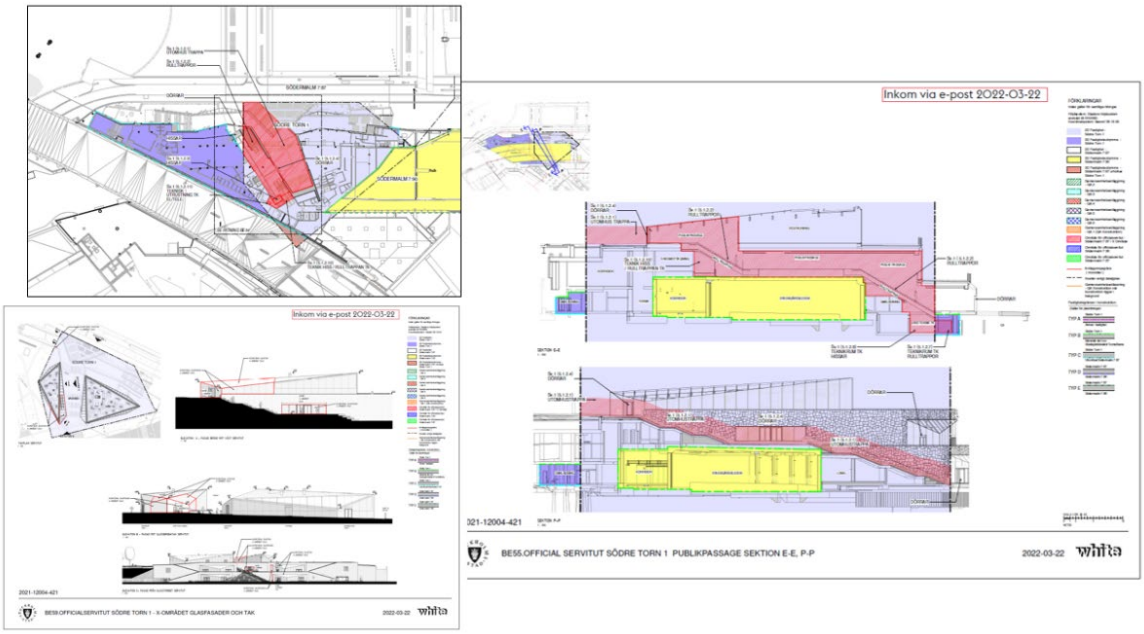


Figure 15. Extract from property formation dossier. Drawings describing boundaries of 2D and 3D property units as well as other RRRs. From the property formation dossier of Södre Torn 1, 0180K-2021-12004. City of Stockholm

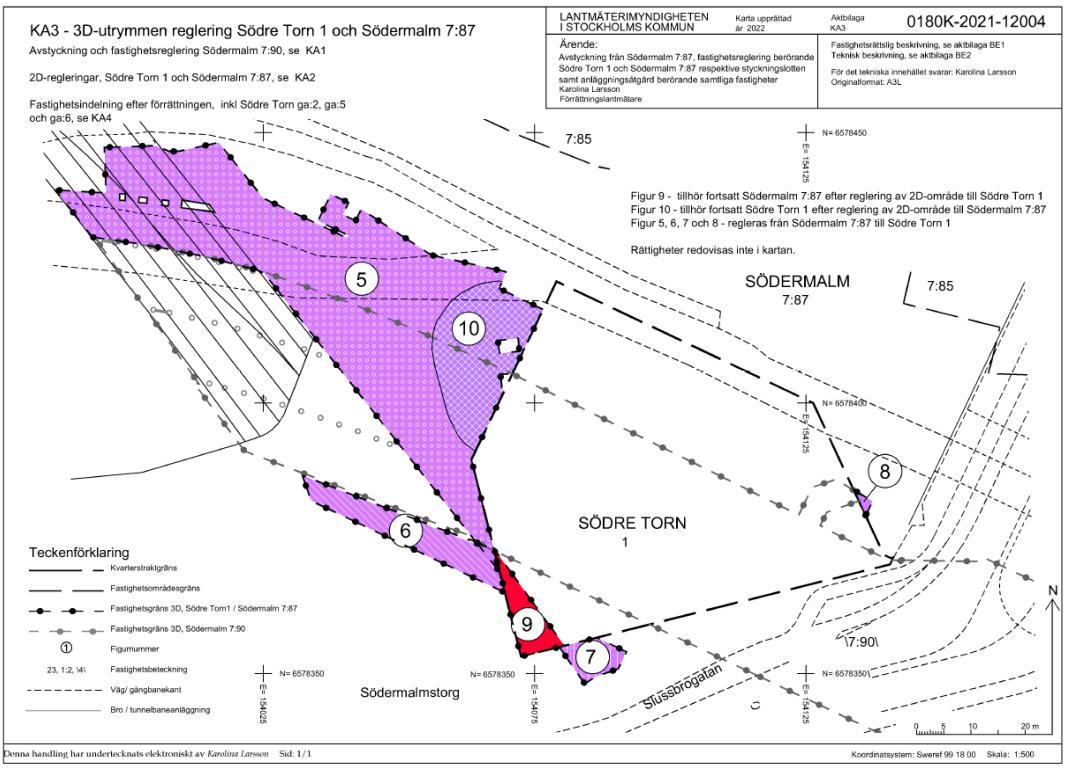


Figure 16. Extract from property formation dossier. Cadastral map no 3 (KA3), showing, among other things, the four 3D property sub-areas of Södre Torn 1. Dossier 0180K-2021-12004. City of Stockholm

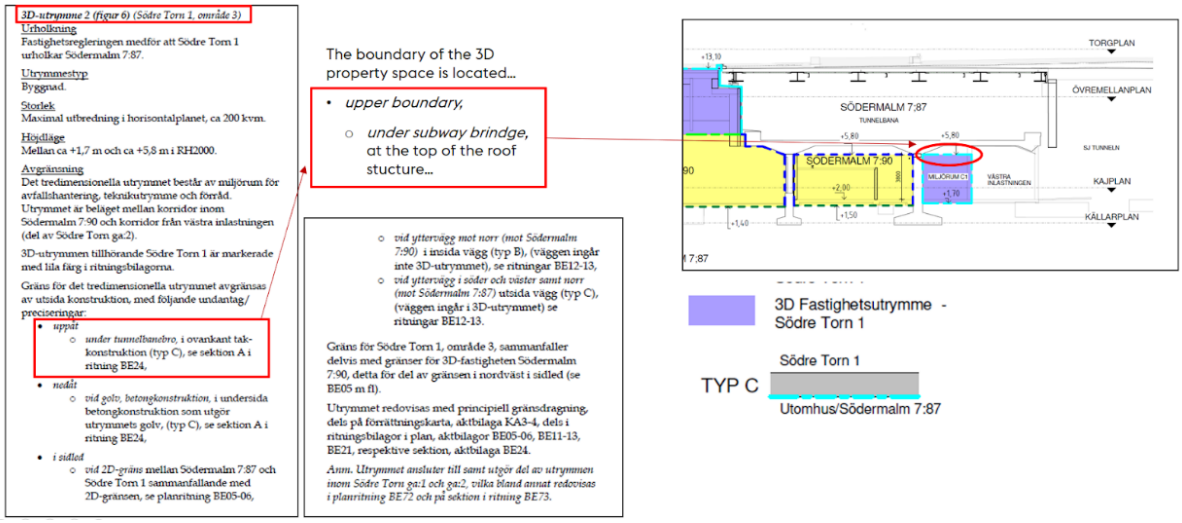


Figure 17. Extract from property formation dossier. Text describing boundaries and the same boundary represented in drawings. Both text and drawings are part of the property formation decision. From the property formation dossier of Södre Torn 1, 0180K-2021-12004. City of Stockholm

Since the area where Södre Torn 1 is located is still a construction site, it is not possible to visit and make sure that the boundaries are located in such a manner that it creates suitable property units, for example regarding their placement in reference to actual building parts such as walls and floors. Therefore, the cadastral surveyor has to rely on drawings and pictures from 3D models and other relevant data when determining that the 3D property unit created is deemed suitable for its purpose.

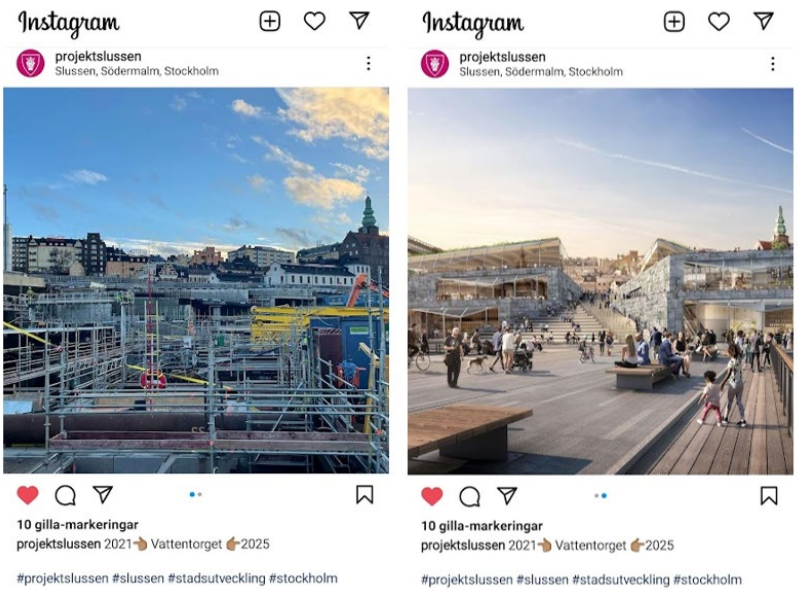


Figure 18. Picture on the right shows what the buildings within the property unit Södre Torn 1 are planned to look like when completed in 2025. Picture on the left shows the actual view of the same area in 2021 when the property unit Södre Torn 1 was about to be created. Adapted from Larsson (2021)

The 3D volumes of existing 3D property units cannot be distinguished in the digital index map, since it only displays objects in 2D. What can be deducted from the map is the maximal spread of each 3D volume. There can be several sub-areas, in 2D and/or 3D, belonging to the same real property unit.

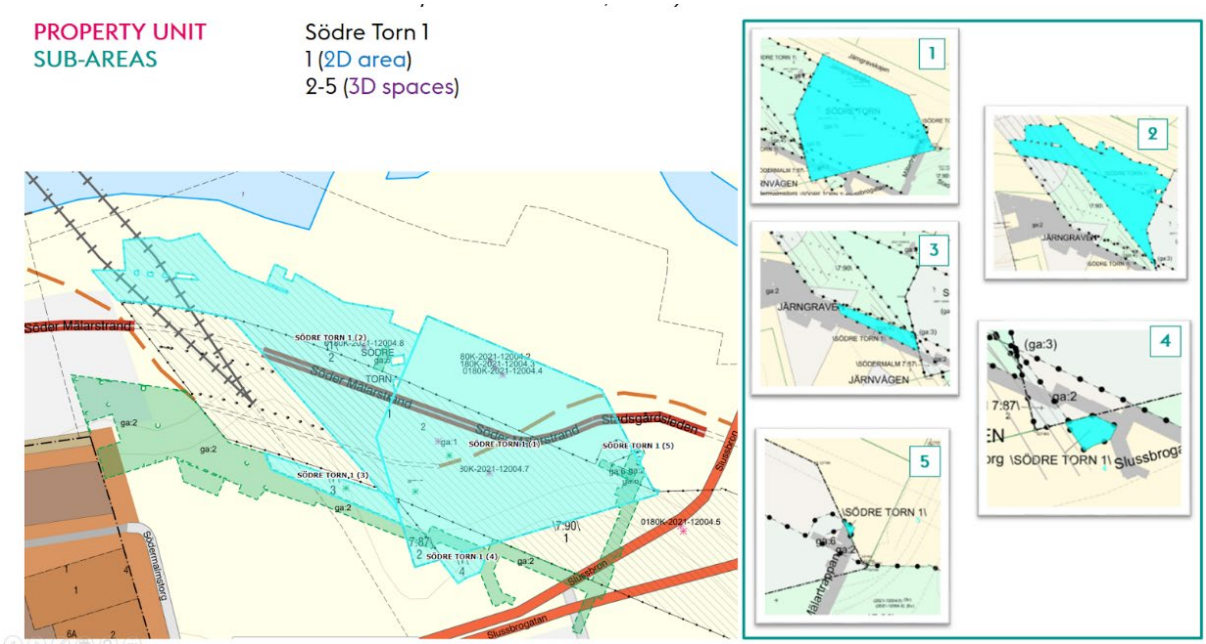


Figure 19. The property unit Södre Torn 1 consists of five sub-units (marked with turquoise), one in 2D and four in 3D. The sub-unit in 2D is partly hollowed by two other 3D property units. 3D property lines are marked by black dashed lines with filled dots on. Some of the existing joint facilities are marked in green in the left picture and grey in the ones on right. Picture on left extracted from the cadastral index map of Lantmäteriet, GeoVy. Pictures on right extracted from cadastral index map of City of Stockholm.

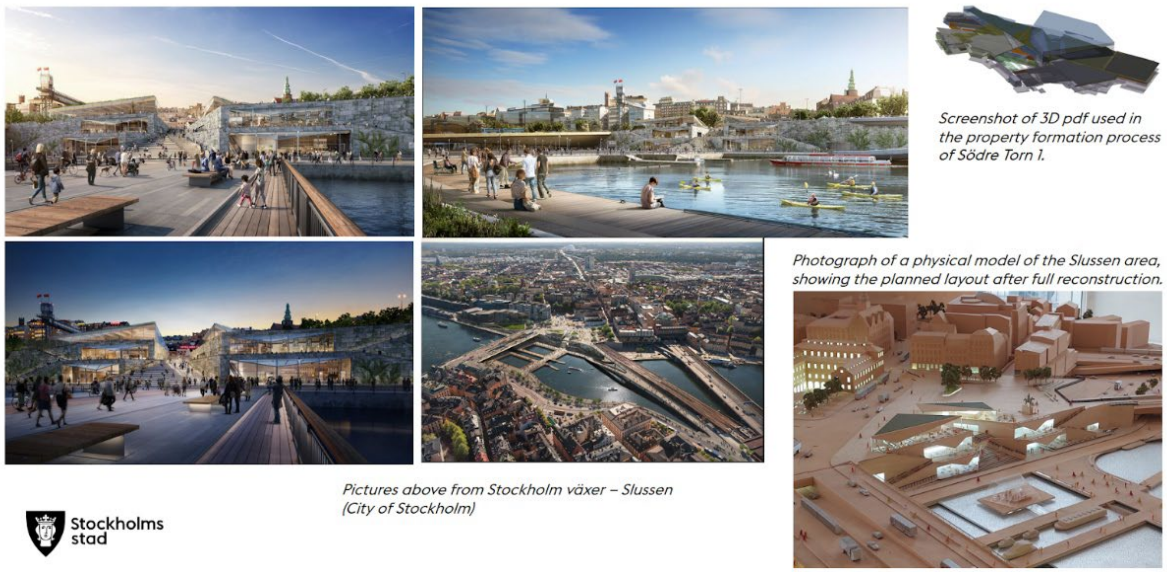


Figure 20. Illustrations of the planned layout of the Slussen area once completed. Adapted from Larsson (2021)

4. ANALYSIS AND DISCUSSION

Sweden has a secure legal process for forming 3D real property boundaries. However, the Slussen project has shown that current methods to register and describe 3D real property in the national real property register is not sufficient in complex building- and infrastructure constructions containing a multitude of RRRs on different levels and extensions, which hinders an effective property formation process. One experience is that it is not possible to be as detailed in the planning phase as in the property formation phase, but the data must be detailed enough so that property formation can be made according to plan. Especially the boundaries between public spaces and the building sites should be clearly visible.

3D digital models of the constructions, such as BIM models, are often used as input in the property formation process. These models are however not stored digitally in the national real property register but reduced to 2D pdf-files making the interpretation of details difficult, especially when a property has to be altered or a new adjacent 3D property has to be formed. It is possible to store models locally at municipality level, but this may give rise to difficulties when e.g. a property has to be formed on the other side of a municipal boundary.
Another issue to be solved is the copyright of the digital building models being used in the property formation process, e.g. by having contractual agreements for further use of the digital information therein, often being owned by the construction companies.

It can be noted that if a 3D model could legally have been a part of the property formation decision for the property unit Södre Torn 1, the boundaries and other RRRs would probably have been easier to describe and visualise.

5. CONCLUSIONS

This paper illustrates the need for a national cadastral index map in three dimensions to be used in the formal real property formation procedures, to achieve a comprehensible and correct representation and visualisation of 3D real properties and RRRs in Sweden.

The results can be used as input in coming property formations of a similar kind, as well as a component for the development of a national three-dimensional cadastral index map. Furthermore, the results can be an input to capacity building for the future use of 3D models as part of the formal cadastral property formation procedure.

It is recommended to investigate the possibilities to change the legislation so that a 3D model can be part of a 3D property formation decision in order to make it easier to describe and visualise 3D property boundaries. Such future solutions would have to include the legal aspects of strategies for archiving property formation dossiers in this form. It is also recommended to investigate whether a national 3D digital cadastral index map is economically and practically feasible to create on a national basis in the future.

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Integrating CityGML and LADM for 3D Building Management - Taking Taiwan as an Example

Sin-Yi HO, Jung-Hong HONG, Taiwan

Key words: CityGML, LADM, 3D Cadastre, Building Management

SUMMARY

The recent advances of surveying and mapping technology has made the collection of 3D information increasingly easier. A variety of real-world phenomena nowadays can be modelled in a realistic way, which enables the development of many innovated applications (Liu Wei Zhe, 2020). Due to the rapid expansion of urban population and limited land resources, the effective management of the right and property of buildings has been considered as one important mission to the digital cadastre. Especially when more and more tall buildings were built in the urban area, modern 3D modelling strategies considering vertical dimensions appears to be an obvious choice for the future cadaster systems. Developing 3D cadastres is therefore widely recognized as an urgent issue for many countries (Zeng Zis Han, 2022). To meet the modelling and encoding demands of city phenomena, CityGML (City Geographic Markup Language) from Open Geospatial Consortium (OGC) has been successfully used to improve the cross-discipline interoperability with its pre-defined and standardized schema (Löwner, Gröger, Benner, Biljecki, & Nagel, 2016). Nowadays, many 3D building datasets around the world are distributed with CityGML (OGC, 2021a). Land Administration Domain Model (LADM) provided a standardized schema for the management of building property rights (Lemmen, van Oosterom, & Kalantari, 2018), which includes contents about party, administrative units and the right, responsibility and restriction between them. The combination of a 3D model and property rights brings great benefits to the development of 3D cadaster (Surmeneli, Koeva, Zevenbergen, & Alkan, 2020), for example, realizing the size and the location of the legal space. Various research has been focusing on the advantages of integrating these two standards. Rönsdorff et al. (2014) proposed a CityGML ADE to model the legal space; Góźdź et al. (2014) proposed a CityGML-LADM ADE model to describe the relationship between the legal and physical representation of selected objects. Nega & Coors(2022) suggested the integration of LADM and CityGML can be used to deal with the problems of overlapping ownerships in buildings, and can be further applied in many scenarios which need to distinguish the legal and physical space. LADM can effectively model the legal and management aspect about buildings, but more discussion about the 3D geometric representation, as well as the links to the various 3D building information, e.g., BIM, 3D mesh model, are still necessary. By considering the regulation, management systems and building characteristics of Taiwan, this research discusses the design strategies for developing a prototype of 3D cadastre system for Taiwan using CityGML and LADM. Although the current result is still preliminary and the modelling scope is limited, we believe it can serve as the basis for further profile development of a complete 3D cadastre system that not only meets the demands of cadaster related application, but also provide a solid reference for the use of land information in smart cities applications.

SUMMARY

隨著測繪技術之進步，三維資訊之取得也愈來愈容易，現今之各種現實世界現象可以更實際之方式進行建模，促使許多創新應用之開發成為可能(劉瑋哲, 2020)。由於城市人口快速增長及土地資源之有限，建築物產權之有效管理已成為數值地籍中重要課題之一。特別是當城市地區出現越來越多高樓層建築，未來地籍系統在現代 3D 建模策略方法研擬中，很顯然需要考慮垂直尺寸之元素。因此，3D 地籍被普遍認為是許多國家迫在眉睫之發展方向(曾子珊, 2022)。

為了滿足城市現象之建模及編碼需求，開放地理空間聯盟（OGC）之 CityGML（城市地理標記語言）已成功使用其預定義及標準化模式來提高跨領域之互操作性(Löwner, Gröger, Benner, Biljecki, & Nagel, 2016)。如今，世界各國許多 3D 建築資料集都是透過 CityGML 開發。對於三維建物模型之幾何具有完整之描述能力，近年來有許多三維建物的表示係透過 CityGML 來達成(OGC, 2021a)。土地管理領域模型（LADM）為建築物產權管理提供了標準化之模式(Lemmen, van Oosterom, & Kalantari, 2018)，其中包括有關人員、行政單位及其之間之權利、責任及限制之相關資訊。三維模型及產權建物之結合對於三維地籍帶來極大之優勢(Surmeneli, Koeva, Zevenbergen, & Alkan, 2020)，例如:對於合法之空間可得知其具體之位置及大小，各領域之研究一直著重於兩項標準結合之優勢，Rönsdorff 等人(2014)利用 CityGML ADE 之作法將合法空間進行對應(Rönsdorff, Wilson, & Stoter, 2014)；Góźdź 等人(2014)創建 CityGML-LADM ADE 模型以提供空間物件合法及物理間之關係(Góźdź, Pachelski, van Oosterom, & Coors, 2014)。Nega 及 Coors(2022)也指出 LADM 與 CityGML 之整合可以用來改善大樓建物對於所有權重疊之問題，並且後續可應用於非常多需要劃分合法與實體建物之場合(Nega & Coors, 2022)。LADM 可以有效地對建築物之法律及管理方面進行建模，但仍然需要對 3D 幾何表示以及各種 3D 建築資訊（例如 BIM、3D 網格模型）之連接進行更多討論。透過考量台灣的法規、管理系統及建築特點，本研究提出使用 CityGML 及 LADM 來開發台灣 3D 地籍系統原型之設計策略。雖然目前的結果還處於初步階段，建模範圍也有限，但我們相信它可以作為進一步開發完整 3D 地籍系統子標準之基礎，不僅滿足地籍相關應用需求，也為後續在智慧城市應用中，對於土地資訊之使用提供了具體之參考。

Integrating CityGML and LADM for 3D Building Management - Taking Taiwan as an Example

Sin-Yi HO, Jung-Hong HONG, Taiwan

1. INTRODUCTION

With the rapid development of large cities, the applications of 3D cadastre become very important. LADM is an extendable, efficient, and effective solution for facilitating the management mechanism of cadastre domain. Experts can design their own profiles based on LADM according to their specific goals and development needs (ISO, 2012). The main goal of LADM is to enable designers of cadastral systems to develop a mechanism for sharing cadastral data based on shared concepts and vocabularies. Many countries have developed 3D cadastre profiles based on LADM, such as Cyprus (Elia, Zevenbergen, Lemmen, & Van Oosterom, 2013), Cape Verde (Andrade, Carneiro, & Santos, 2013), Croatia (Mader, Vucic, Vranic, & Roic, 2018), Korea (Lee, Kim, Kwak, Lee, & Choi, 2015; Park, Lee, & Li, 2010), and Poland (Bydłosz, 2015). The development of a country profile may vary due to the different needs and considerations for each country. As the nation GISs evolve, the integration of data from different resources begins to receive increasing attention. For example, the source of building data may widely involve different stakeholders, e.g., urban planning, construction, cadastre, mapping, tax property, building facility management, BIM (Building Information Modeling), photogrammetry, format, topographical and built context information in CityGML, and LandXML (K. H. Soon, Thompson, & Khoo, 2014).

Although LADM can express the legality and management from a building perspective, it cannot satisfy the description of semantics and 3D space. CityGML has been adopted by many countries and cities as the modeling standard for 3D surveying and mapping projects. In Berlin, Germany, a method for the efficient transfer of large and highly detailed 3D city models was developed based on CityGML (Schilling, Bolling, & Nagel, 2016), Singapore Land Authority (SLA) use CityGML to develop a Whole-of-Government (WOG) 3D mapping project for the purpose of creating and maintaining a 3D national map of Singapore (K. Soon & Khoo, 2017). The city of Rijssen-Holten in the Netherlands created an energy application test platform based on a semantic 3D city model. The data is stored in accordance with the CityGML 2.0 standard, including geometric and semantic information (León-Sánchez, Agugiaro, & Stoter, 2022). The integration of LADM and CityGML has a potential to bring great benefits to the management of 3D building information, whether it is the overall space description or the management of property rights (Surmeneli et al., 2020). Take the modelling of legal space as an example, its specific position and size can be known. What's more, two abstract classes AbstractSpace and AbstractSpaceBoundary strongly motivated by urban planning, the work on IndoorGML and indoor navigation as well as the Land Administration Domain Model(Kutzner, Chaturvedi, & Kolbe, 2020). Rönsdorff et al. (2014) developed a CityGML ADE to map the legal space (Rönsdorff et al., 2014), Góźdź et al. (2014) also developed a CityGML-LADM ADE to model the legal and physical relationships between spatial objects (Góźdź et al., 2014). Soon et.al. (2014) adopted the ePlan conceptual

model, extended the concept of LADM OWL ontology, and integrated with CityGML's building module without changing the existing schemas (K. H. Soon et al., 2014). Turkey has also proposed a new cadastral model based Land Administration Data Model (LADM) and CityGML to maintain complex relationships in land sales, donations, taxes and mortgages, and to support the cadastral information systems (Surmeneli et al., 2020). In Taiwan, we have built a process for 3D cadastral model production, and the Ministry of the Interior has promoted the "Multi-propose Cadastral Map Construction Project". Based on the result map of building survey, a floor plan is established, and the floor heights shown in the building's as-built drawings are stretched to create a three-dimensional property rights. Hong Jonghong, Jiang Hunchin et. al also analyzed the three-dimensional property rights building data based on Taiwan's existing regulations, and further proposed relevant profile based on the package of the Land Administration Domain Model (LADM) (Jiang Hun Chin, 2019; Hong Jong Hong & Zeng Zis Han, 2021).

2. STANDARDIZATION

2.1 CityGML

CityGML provides a standardized 3D data model for the selected themes of city information. The development of CityGML intends to reach a common definition of the basic entities, attributes, and relations of a 3D city model. This is especially important with respect to the cost-effective sustainable maintenance of 3D city models that allow the reuse of the same data in different application domains (Gröger & Plümer, 2012; *OGC City Geography Markup Language CityGML Encoding Standard*, 2012). One of the main concepts in the standard is LOD (Level of Detail), which specifies 3 levels for the modeling criteria (Schilling et al., 2016) and differentiate multi-scale representations of semantic 3D city models (Biljecki, Ledoux, & Stoter, 2016b). CityGML, there defines includes 16 thematic modules respectively designed for modelling the aspects of appearance, bridge, building, cityfurniture, landuse, relief, transportation, tunnel, vegetation, waterbody. By extending the defined classes to design a description framework that conforms to the characteristics of the feature, data providers can combine different thematic modules according to the needs to form the city model (Liu, 2020). The building module provides the representation of thematic and spatial aspects of buildings. Buildings is the top-level feature type building, which is the main class of the building module. Buildings can be subdivided into building parts physically or functionally, and logically subdivided into storeys and building units (e.g., apartments) (Kutzner et al., 2020). Moreover, building can be also aggregated from the class of building room, furniture and installation. Features are modelled with specific LOD. To create a 3D cadastre, each city features must first be modelled with appropriate LOD (Nega & Coors, 2022).

The temporal aspect of buildings, city model includes the different phases of its life cycle, e.g., architectural design, urban planning and procedural modelling (Biljecki, Ledoux, & Stoter, 2016a). The temporal information of city objects is recorded by the attribute of AbstractFeatureWithLifespan class (OGC, 2021b). AbstractFeatureWithLifespan class extends AbstractFeature with temporal properties for the related classes. It contains the following attributes: featureId, identifier, name, description, creationDate, terminationDate, validFrom, validTo, and adeOfAbstractFeatureWithLifespancreationDate. Most of the feature

classes in the CityGML model are descended from this class. The attributes of terminationDate, validFrom, and ValidTo are respectively designed to represent feature creation time, feature termination time, phenomena happening time, and phenomena disappear time. 3D city model can be composed of various versions of an object referring to the time period, additionally have the attributes validFrom and validTo, which represent the lifespan a specific version of an object has in the real world(Kutzner et al., 2020).

2.2 LADM

The Land Administration Domain Model (LADM) is an international standard (ISO19152) designed to serve as the common conceptual model for administration issues of lands, such that related stakeholders can communicate with each other based on the same model and a set of shared vocabulary (ISO, 2012). The purpose of LADM is to provide a more comprehensive conceptual schema and offer a standardized description to remove the heterogeneity and enable the development of interoperable applications (van Oosterom et al., 2019). It defines four packages to describe the relationship of land administration, including water and elements above and below the earth's surface, as well as people (Lemmen et al., 2019). The party package records the basic information of the right subject, spatialunit package keeps the land or building information, administrative package describes the status of the RRRs (Right, Restriction, Responsibilties), and surveying and representation package stores the surveying result about the spatial unit.

Temporal is a necessary consideration for cadastral management. The class of VersionedObject in LADM is specifically designed to manage and maintain the historical data . As most of the classes in the four packages inherit from the class of VersionedObject, their temporal relationships can be established accordingly. The semantics of the inherited attributes of beginlifespanversion and endlifespanversion can be respectively determined according to the feature types. For example, the class of LA_Party is used to record the information of a person or a company, the begin and end time represent for the birth date / found date and death date / close down date. The same pair of attributes represent the begin and end time for the described right/responsibility/restriction. For the spatialUnit package, it always represents for the data transaction time. Another set of classes include the class of LA_Source, LA_SpatialSource and LA_AdministrativeSource, four attributes of lifespanstamp, submission, acceptance, and recordation were designed to record the specific time points of the source document with pre-defined semantics.

2.3 Integrating CityGML and LADM

Based on the above discussion, LADM focuses on the description of cadastral objects, while CityGML focuses on the descriptions of urban objects. Although these two standards were independently designed with different schemas, both can be used to describe buildings in the real world. Open data standards such as CityGML and Industry Foundation Classes (IFC) play a vital role to improve the interoperability between different domains, such as architecture, engineering and construction (AEC), while LADM was developed to facilitate the modelling needs of cadaster applications that include land and buildings. In 3D cadastre, if the LADM standard is used alone without cooperating with the CityGML standard, it still cannot solve the influence of blurred rights. In contrast, if LADM is integrated with the CityGML standard, the cadastral structure of the overall building can be clearly

described(Gürsoy Sürmeneli, Alkan, & Koeva, 2022). Aien et al. (2013) proposed a collaborative operation framework between LADM and CityGML by using LegalPropertyObject and PhysicalPropertyObject to represent the cadastral object to be described and the corresponding city object respectively, which can have a more realistic 3D objects in the 3D cadastral world(Aien, Kalantari, Rajabifard, Williamson, & Wallace, 2013). Góźdź et al. (2014) proposed an innovative model based on CityGML-LADM ADE model provides relations between spatial objects from the legal and physical world (Góźdź et al., 2014). ADE is a mechanism that can enrich the data model with new feature classes and attributes and keep the semantics structure in standard at the same time. Gürsoy Sürmeneli et al. (2021) proposed a new integrated data model using LADM and CityGML v2.0. This model integrates LADM and CityGML through the framework of ADE, which supports the legal and administrative concepts defined in Turkish law for cadastral objects (Gürsoy Sürmeneli, Koeva, & Alkan, 2021). As there are multiple sources of 3D building information from other stakeholders, the open architecture that enables the integration of CityGML and LADM provides an effective strategy to facilitate the interoperable applications cross different disciplines.

3. 3D CADASTRAL BUILDING MANAGEMENT FRAMEWORK OF TAIWAN

The current registration of building property rights in Taiwan is mainly based on 2D model. The initial registration of constructional improvements is based on the result map of building survey by the local land administration agency. A building number system is developed to meet the demands of unique identification. The result map of building survey consists of building location map, building floor plan, area calculation and attribute information (such as building number, main use and area, etc.). As 3D GIS data receives more attention in recent years, 3D cadaster that aims to add the consideration of vertical dimension to the land administration also becomes a challenge. Therefore, the Ministry of the Interior of Taiwan began to assess the possibility of applying LADM to land management data. The "multi-propose cadastral map with three-dimensional data construction project" was the first attempt of using LADM to link the building registration data and its 3D geometric representation (Jiang, 2017). Zeng & Hong (2021) further develop a hierarchical framework of the three-dimensional space units in the buildings from the perspective of property rights and demonstrates three advantages, (1) combining land affairs and regulations to define the internal spatial structure of the three-dimensional building, (2) 3D visualization of building property rights information and (3) effective managemnt the property of spatial units according to the semantic listed in the building specifications (Zeng Zishan & Hong Junghong, 2021).

According to the "Implementation Rules for Cadastral Surveying" in Taiwan, property rights buildings can be divided into two types: "non-condominium building " and "condominium building". Non-condominium building indicates one property with one right, which means that the same building belongs to the same owner, such as single-family buildings (house), schools, factories, warehouses, temples, etc. A condominium building is one property with multiple rights means that the same building belongs to several owners, such as apartments, mansions, building blocks, etc.

3.1 Overview of Building Registration in Taiwan

The building registration system in Taiwan adopts an arbitrary registration system for the registration of buildings. As the law does not mandate the registraton of buildings, the buildingsrecorded in cadastre database does not represent all the buildings in the real world.. A legal building is defined as a building with a construction license issued by the government. the ownership of buildings that have not been registered cannot be transferred, but other dispositions can still be freely carried out, such as inheritance, lease, etc. In addition, if the owner wants to apply the initial registration to obtain a certificate of ownership, the building must be a legal building. The major characteristics of the building registraction in Taiwan are summarized as follows:

(1) The initial registration of building ownership is arbitrarily registered. Owners can decide whether to apply for ownership registration to the land administration office or not. Even if the ownership registration is not completed, s legality of their private ownership is still valid.
(2) Complete the initial registration of ownership (save registration) and confirm the ownership directly - go through the initial registration of building ownership with the Land Affairs Office, and the acquired property right is a legal building, which has absolute effectiveness in accordance with Article 43 of the Land Law. It is reminded that when buying and selling, the property rights registered by the land administration authority should prevail.
(3) The apartment building is divided into three types: the exclusive part, the common part and the part due to land rights. These will be stated separately when registering. If there is a sale, gift or other transfer, the three parts shall be transferred together. Or set up to make property rights clear.

The current registration data can be subdivided into two parts: spatial data and registration data. The building registration data includes six types of data, namely, related rights of land and building, identification of land and building, registration information, information of subjects, transaction index, and historical data. In addtion to the cadastre databases, these data is also recorded in the related document of the building, such as building ownership certificate, building registration transcriptions. Another kinds of data is the map data that includes cadastral maps, floorplan, result map of building survey, as-built drawing, etc. The following further explains the related data that will be included in the scope of this research:

- Building registration transcriptions: The identification part in the transcription records basic information about the real estate. For example, the registration date of the building, the reason for registration, the area, the building construction number, the date of construction completion, and the area of accessory buildings, usage, the area of the common part and the scope of rights, etc.
- Building ownership certificate: This certificate records the ownership information of the building, including thereal estate owner, area, holdings, land number, house number, etc.

and map:

- Floorplan: Each floor of the building is separately surveyed and drawn on the floor plan. The floor plan of each floor should indicate its level, arcade, and accessory buildings, and have the information of "direction", "building distance" and "relationship with adjacent rooms and balconies".

- Result map of building survey: After the surveying finished, the result map of building survey has been created. It contains the information of serial number of the building, the lot number, the address number, the use license number, the main structure, the main use purpose, and the individual and total areas of the main building and accessory buildings.
- As-built drawing: After the construction is completed, it is drawn on the paper according to the completion status of the construction site, including basic information and details such as project name, construction purpose, construction location, construction unit, supervision unit, design unit, construction unit, construction area, structure type, and number of floors, and house interior structure.
- Construction license: As long as there is physical construction or renovation of the house, this kind of license is request. Therefore, including new construction, additions, alterations, construction, etc., need to apply for a construction license. This license includes the names of the builder and designer, usage type, structure type, construction category, construction location (address, land number), number of floors, building coverage ratio and floor area ratio, license issuance date, etc.

The above inforamtion recorded in the database and docuents serves will serve as the sources of the schema design in this research. For example, the building ownership certificate is related to LA_RRR and LA_Party, building registration transcription is related to LA_RRR, LA_Party, LA_BAUnit, and LA_SpatialUnit. The floorplan, building registration transcription, as-built drawing, and construction license are related to the classes in CityGML building module, such as building, buildingInstellatoin, storey, buildingRoom.
Based on the above analysis, unique building number is listed in almost all building-related documents. It can hence serve to link various building space units. In Taiwan, the building unit contains four levels, building block, building, storey, and household. The relation between them is shown as Figure 1. One building block consists of multiple buildings, one building can correspond to one to many stories. The corresponding relationship between storey and household can be many to many. Each household unit has a building number, which is the unique identifier.

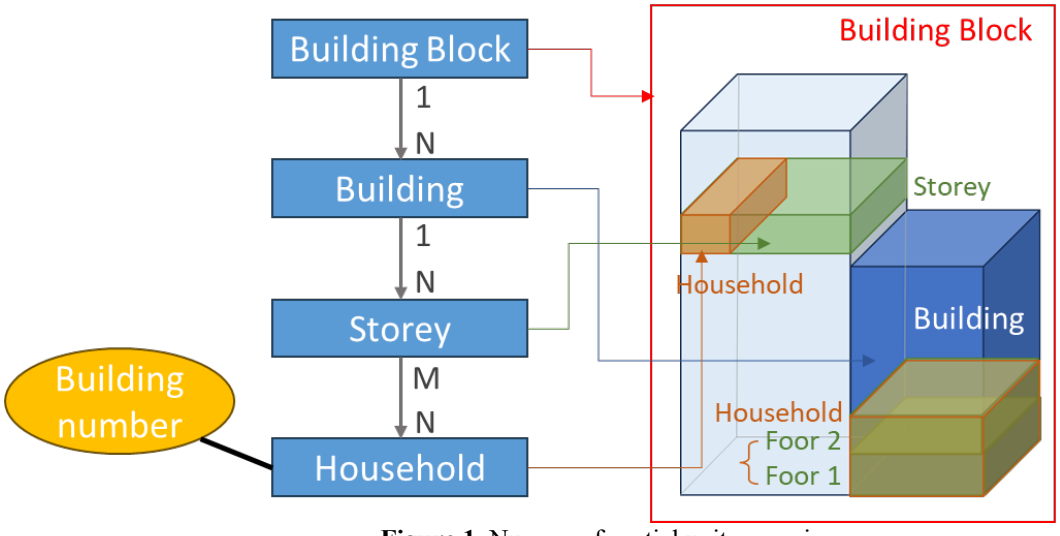


Figure 1. Numers of spatial units mapping

3.2 Design Strategy of CityGML Taiwan Profile based on the building unit management in Taiwan

Based on the space unit in Taiwan, four levels of classes, building block, building, storey andhousehold were designed in CityGML Taiwan Profile. An additional class about building number was also designed for establishing the links between designed space units.

- Building block: The largest unit of building management unit in Taiwan. The building block unit is rarely used in the registration, but it can be used to link the neighboring buildings built at the same time and share similar information. The information can be recorded in the construction license including ID, address, land number, number of storeies, and households. There is no similar class in CityGML, thus, we desinged an additional class named TW_BuildingBlock.
- Building: The class of building is the most common building management unit in Taiwan. Many documents contributes certain information about building, e.g., result map of building survey, building registration transcriptions, building ownership certificate, and as-built drawing. Follow Building class in CityGML class and design a inheritance relation to TW_Building class. The attributes include id, address, land number, building number, number of storeies and households.
- Storey: Since most building has more than one floor in Taiwan, many documents are able to describe multi-storey scenario, for example, in the map data such as floorplan, result map of building survey, as-built drawing and in the text document such as building registration transcriptions, building ownership certificate all includes the storey content. The class of TW_Storey is defined by extending Storey class in CityGML with attributes of id, land number, building number, floor, and the number of households.
- Household: In Taiwan, the basic unit of building management is based on individual household. The information can be recorded in the result map of building survey, building registration transcriptions, building ownership certificate and as-built drawing. According to current specificaiton, a household may include two parts: main building and accessory building. Because there is no similar class in CityGML, a new class named TW_HouseHold is defined. Its attributes include id, land number, building number, floor, and the type of household (main building or accessory building).
- Building number management unit: Building number is the main id to manage the building in Taiwan, many types of data include building number as its attribute.A new class of TW_BuildingNumberManagementUnit is defined for the purpose of unique identification. This class can be used in the result map of building survey, building registration transcriptions, building ownership certificate and building ownership certifica. One building number corresponds to one household. The attributes including building number, boundary points number, address, structure, useType.

Figure 2 depicts the UML for each level of sp The following explains the information contained in various documents and how to design the Taiwan profile based on CityGML (Table 1).

- Information from various types of building documents, such as floorplan or result map of building survey, are modelled as the space units with correct semantic.
- According to the building registration rule in Taiwan, classes are designed to extend the Building module by adding attributes specifically designed for the requirements of

Taiwan cadastral systems, such as building number, address, boundary points number, structure, and etc.

- According to the current cadastral system in Taiwan, classes are designed to account for the description of various types of building ownership, such as single-ownership building types and complex multi-ownership apartment types.

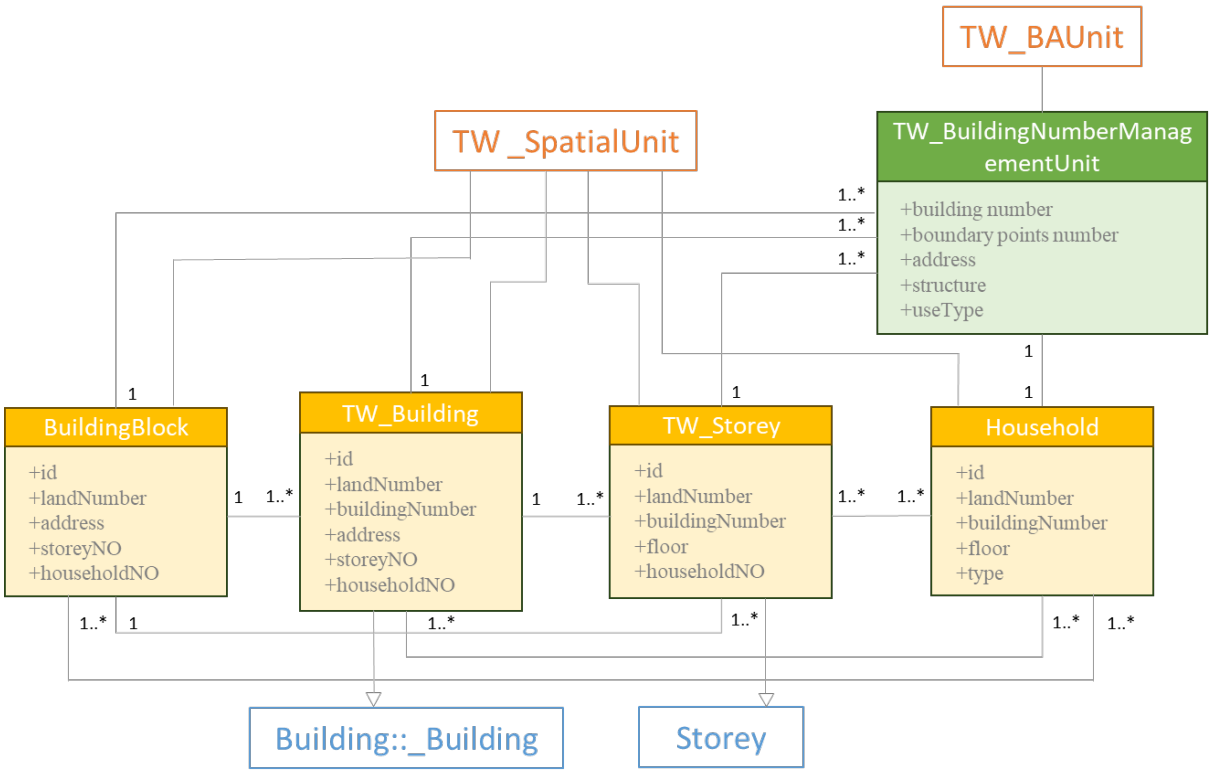


Figure 2. UML of the basic building unit level

Table 1. Summarize the design strategy of CityGML-based Taiwan Profile

Documents from Current Cadastral System	**Building Space Unit**	**CityGML class**	**Design Strategy**
Construction license	Building block		Add a new class-TW_BuildingBlock
result map of building survey, building registration transcriptions, building ownership certificate, as-built drawing	Building	Building	Add some attributes to-TW_Building
floorplan, result map of building survey, building registration transcriptions, building ownership certificate, as-built drawing	Storey	Storey	Add some attributes-to TW_Storey
result map of building survey, building registration transcriptions, building ownership certificate, as-built drawing	HouseHold		Add a new class-TW_HouseHold
result map of building survey, building registration transcriptions, building ownership certificate, building ownership certificate	BuildingNumberManagement		Add a new class-BuildingNumberManagement

3.3 Introduction of Taiwan LADM profile preliminary plan and design strategy of Taiwan Cadastral Profile based on LADM

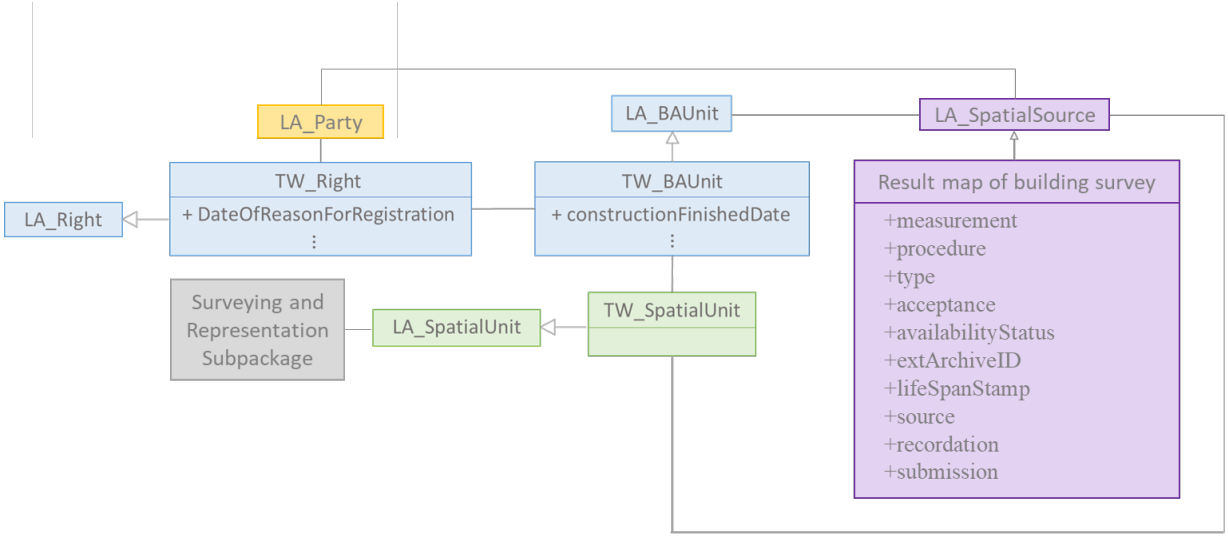


Figure 3. Taiwan LADM profile preliminary plan

By choosing the building registraton as the target, Figure 3 shows the preliminary research results. The design basically follows the classes designed by LADM. The core classes are Party, RRR, BAUnit and SpatialUnit. The TW_Party, TW_Right, TW_BAUnit and TW_SpatialUnit classes are designed in consideration of the characteristics of the cadastre systems through inheritance from LADM classes and expansion of attributes. The related description classes of the surveying and representation sub package are mainly represented by the LA_BoundaryFace, LA_BoundaryFaceString, and LA_Point classes are designed by LADM. Related reference documents such as the result map of building survey are represented by the class of TW_SpatialSource, and the building ownership certificates are represented by the LA_AdministrativeSource class. LA_SpatialSource inherit a new class called Result map of building survey, which records the attributes of measurement, procedure, type, acceptance, availabilityStatus, extArchiveID, lifeSpanStamp, source, recordation, submission. The result map of building survey is the map produced after the measurement of each building. The content includes the location map of the building. It can be seen which land the building is located on, its position and orientation; there is also a floor plan can realize the shape and size of the building, as well as the location and size of the accessory buildings such as balconies. The basic information includes the serial number of the building, the lot number, the address number, the use license number, the main structure, the main use purpose, and the individual and total areas of the main building and accessory buildings, just like the ID of a house, is very important information, allowing the public or real estate practitioners to understand the relevant information of the building without going to the scene. TW_BAUnit class added constructionFinishedDate attribute to record the completion date of the building, and TW_Right added DateOfReasonForRegistration attribute to separate the date of occurrence and registration of the cause date, because the effective time of rights is the registration time, this time is not equal to the time that the event that caused the change of rights occurred. For example, the transfer of land ownership is caused by the act of buying and selling, but the actual effective time of the transfer of ownership is not the time of buying and selling, so the land transcript will record the date of registration and the date of the cause

(the date of signing the sale and purchase agreement). These are two time at which the data are considered to become valid and no longer considered to be valid, which are strongly related to the legal status.

3.4 Taiwan Building Management Profile

Through inherit, add new classes/attributes, and built the relations are three main methods to design a profile. Based on the perspective of properties, the suggested Taiwan Building Management Profile is shown as Figure 4. We designed the new class (green color), which inherit from LADM(orange classes) and CityGML(blue classes) to link two standards. According to the building management level in Taiwan, we designed the building block, building, storey, and household level to aggregate from building number management unit.

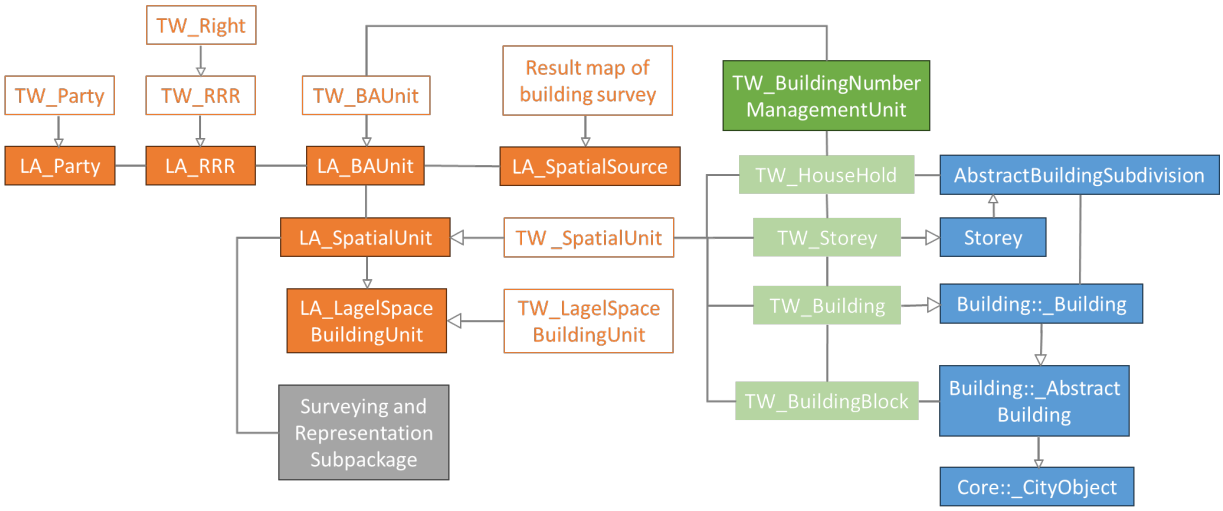


Figure 4. Taiwan Building Management Profile with Integration of LADM and CityGML

The architecture of Taiwan Building Management Profile is based on the LADM to support various cadastral management, and CityGML to represent the space more accurately, therefore, a more powerful 3D expression model for cadastral property building was created. The data from this profile can be provided by different sources and integrated together with the basis of LADM and CityGML. LADM-based Taiwan Building Management Profile adds TW_LegalSpaceBuildingUnit, TW_SpatialUnit, TW_RRR, TW_Right, TW_Party, TW_BAUnit, and Result map of building survey class. Each class designed as the section 3.3 mentioned. In order to have a better strategy to manage 3D cadastral property building, we create a TW_BuildingNumberManagementUnit class to records the building number, which are basic information for the property building in Taiwan as well as other information, such as boundary points number, address, structure, and useType, these data can be obtained from the result map of building survey. TW_BuildingNumberManagementUnit is related to BAUnit class so that it can link to LADM, and further to design the class to express the relation between BuildingNumberManagementUnit and each building unit level in Taiwan, including TW_BuildingBlock, TW_Building, TW_Storey, and TW_HouseHold class, just as Figure 4 shows. Each building unit level class created in the paper all relate to TW_SpatialUnit class and can be inherited from or related to CityGML class.

4. TEST ANALYSIS

Through the structure of Taiwan Building Management Profile proposed above, this section discusses the recording methods of non-condominium buildings and condominium buildings:

a. Non-condominium building (House) - The house in Taiwan usually defined as a single building and we discuss this house only has one owner. The record strategy shows as follows:

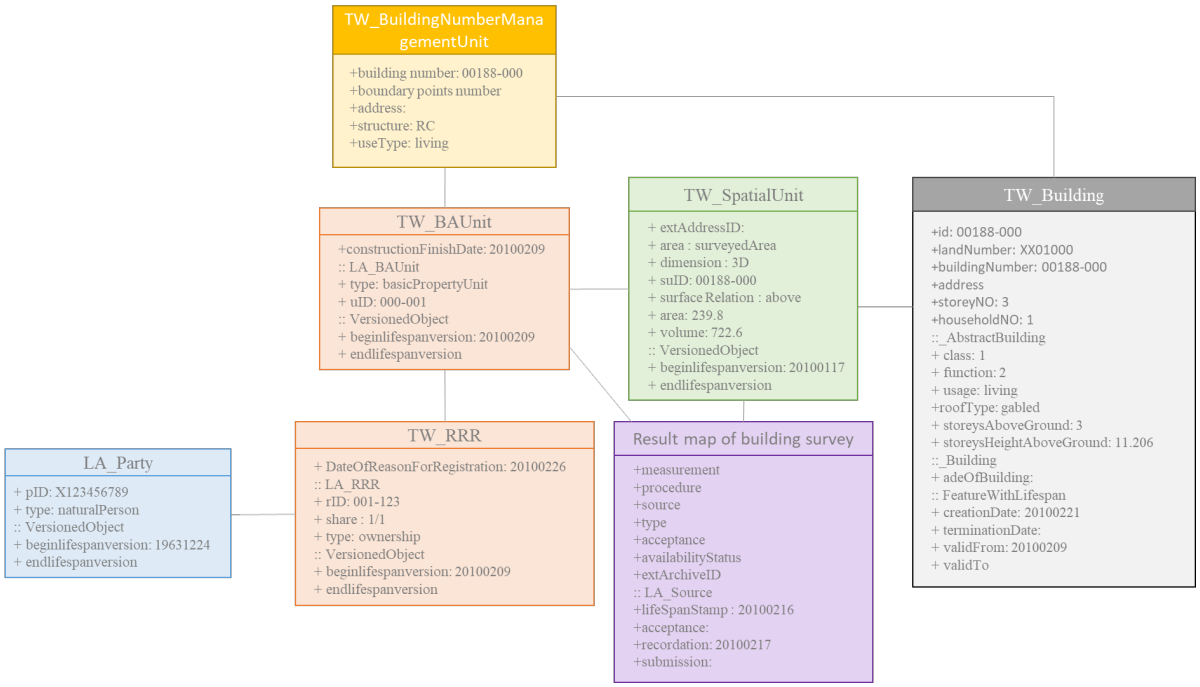


Figure 5. Taiwan Building Management Profile Recording for house case

The recording situation of the house is shown in Figure 5. This case is about a third-floor house with one owner. The share attribute is 1/1 in TW_RRR class. The BuildingNumberManagementUnit class just relates to a Building class.

b. Condominium building (Condominium) - There are many household units in condominium in Taiwan, namely, many households in the same building and have the land holdings. The condominium includes the main buildings, accessory buildings and public facilities, which belongs to common ownership.

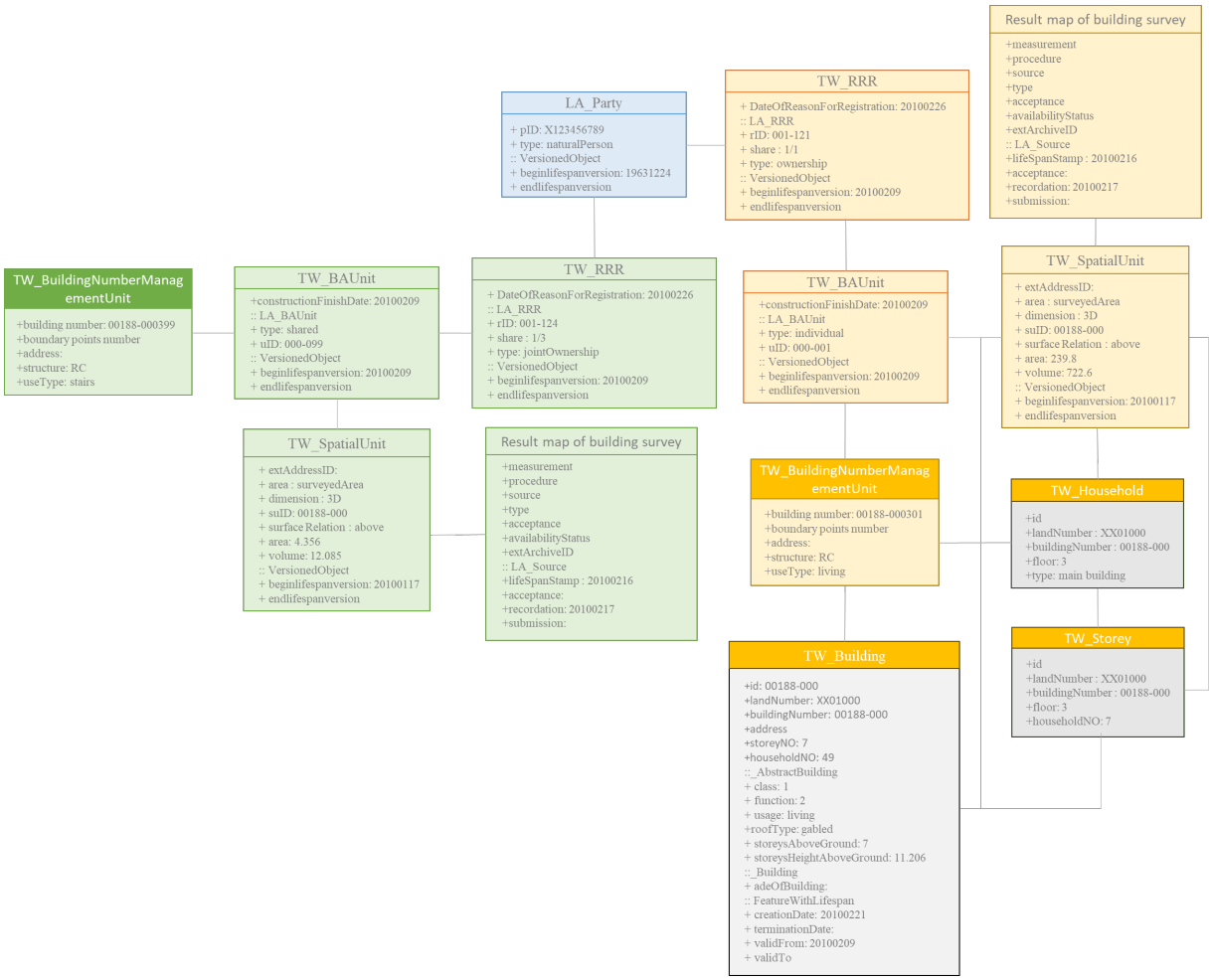


Figure 6. Taiwan Building Management Profile Recording for condominium case (personal ownership and common ownership)

The recording situation of the condominium is shown in Figure 6 and Figure 7. In this case, it is a condominium with seven floors, and there are three people to share this building. Figure 6 shows the case of personal ownership and shared ownership. Since the part of space in the condominium is for public such as stairs, parking lot, yard, and so on. Therefore, each resident has their own household and public space. In Figure 6 the yellow classes are individual ownership, and the green classes are shared areas. Both the individual and shared area has its own building management number. Another issue in the condominium case is many people live in the same building, that is, there are so many households and one BA_Unit class can correspond to many RRR classes. Just as Figure 7 illustrates, there are three people, owner 1 owns the first and second floors, owner 2 owns the third and fourth floors, and owner 3 owns the fifth, sixth, and seventh floors. Each person belongs to one ownership, which is related to one spatialUnit class respectively, and also one household, thus, the first floor and second floor relate to the household of owner 1, the third floor and fourth floor relate to the household of owner 2, and fifth floor, sixth floor, and seventh floor relate to the household of owner 3.

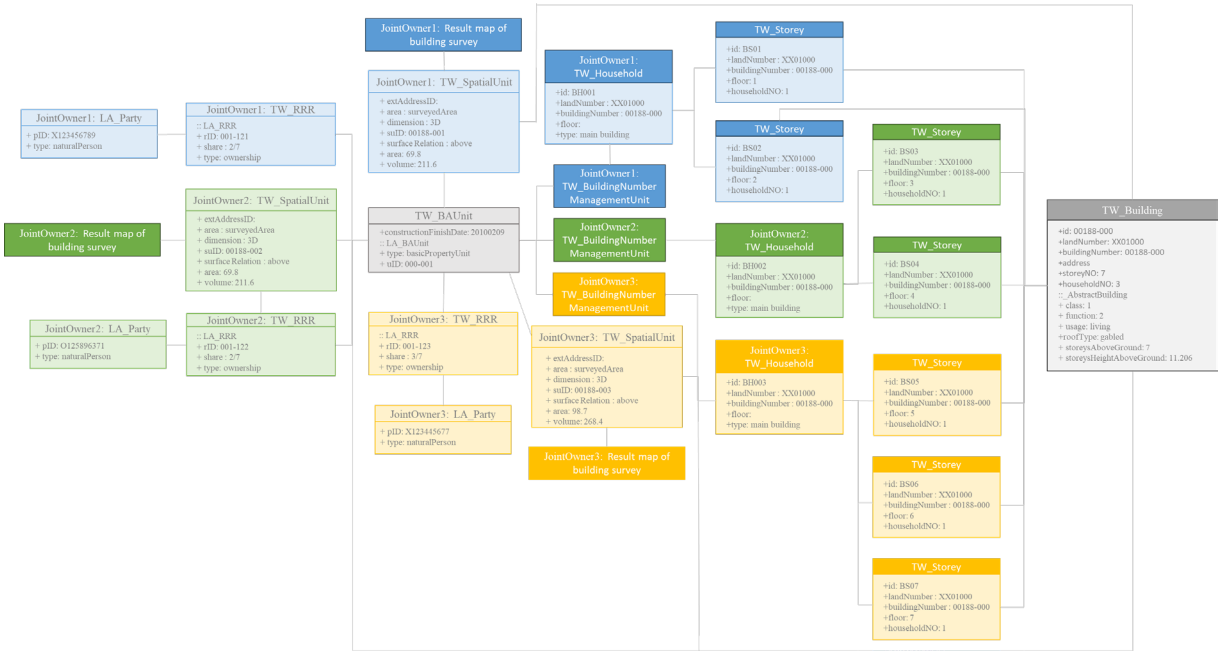


Figure 7. Taiwan Building Management Profile Recording for condominium case (common ownership)

5. CONCLUSIONS

This paper made an overview of the background of current building registration and the types of buildings in Taiwan. According to the cadastral management rule and characteristics in Taiwan, we develop a Taiwan Building Management Profile based on LADM and CityGML. The main contribution in the profile is summarized below:

- TW_BuildingNumberManagementUnit class is designed to use building number as the basic building management unit, based on the administrative unit in LADM and relate to the BAUnit class.
- TW_BuildingNumberManagementUnit class is further related to the spatial unit level which is additional added according to the cadastral law in Taiwan, including building block, building, storey, and household.
- The basic unit level classes (TW_BuildingBlock, TW_Building, TW_Storey, TW_HouseHold) are extended from CityGML and related to SpatialUnit class in LADM.
- According to our cases, we have successfully shown that the characteristics of different cadastral buildings in Taiwan, whether single ownership or joint ownership, can be described according to different building number management units. The common structure is enough to describe the internal ownership structure of condominium units.

Finally, the use cases have been successfully revealed the profile we proposed in this paper could be useful while recording the various types of building in Taiwan. The integration of LADM and CityGML enables the cadastre to bridge the gap between the property description and the scope in the real world.

6. FUTURE WORK

In addition to these advances, there are limitations to applying all the property building for land management in Taiwan. For example, in addition to the building unit like building block, building, storey, and household, we also distinguish the main building, the accessory building, and the space underground. In the future, a more precise profile should be adopted includes:

- More fully incorporate the space management units at all levels defined by Taiwan's building regulations, such as adding underground space units, household space units divided into main building and accessory building space units, and additional attributes that comply with Taiwan's building records.
- Design identification code attributes for various three-dimensional space units and link building management units at all levels to facilitate the unique identification of a single three-dimensional space unit in subsequent applications.
- It can clearly record the hierarchical relationship between different three-dimensional space units, and can be applied to different types of building types in Taiwan, such as single-household building, apartments, mansions, buildings, building block and schools, etc.

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BIM, 3D cadastral data and AI for urban management - A case study for energy consumption monitoring

Dimitra ANDRITSOU, Christos ALEXIOU and Chryssy POTSIOU, Greece

Key words: Digital Twin, Artificial Intelligence, 3D Cadastral Data, Energy Consumption, Urban Management

SUMMARY

Nowadays, many rapid and sudden changes take place in the economics, political and environmental sectors upstirring a sense of uncertainty and causing daily costs to skyrocket. The reduction of energy consumption and cost savings are extremely vital for an auspicious daily life. Another characteristic of the present times, is the catapult of the Artificial Intelligence technology and its utilization for the betterment of the functionality of scientifical, fiscal, social, ecological, communicational, engineering, etc. fields. Amidst all the above, this paper is a part of an ongoing research aiming to create a pioneering low – budget methodology for eventually constructing the complete virtual simulation of an urban neighborhood as a DT (Digital Twin) combining both AI – generated data on energy consumption and 3D cadastral information. This paper aims to combine BIMs (Building Information Models) with an API (Application Programming Interface) for the timely tracking of the functionality of building devices through AI generated sensors. The BIMs of the various buildings, old and new, are modelled utilizing 2D open data and 3D free – to - use platforms, cutting down on production costs and encouraging public participation. The various legal spaces and properties are represented as 3D prismatic volumes, with the insertion of additional cadastral, semantic and geometrical information. The BIMs are equipped with building elements, operational equipment and everyday furniture. The equipment entails electrical, mechanical, communicational and pluming devices. It also involves lighting fixtures, heating, ventilation and air conditioning units. The devices become smart, as they are interconnected with AI – generated sensors that provide dynamic data on energy consumption, efficiency and cost for the time period of an entire day. Sensors can be turned on or off indicating the status of the respective device, fixture or system. Each device can have numerous types of sensors resulting into different groupings. The sensors provide data such as temperature, luminance, voltage, duration of operation, capacity, etc. An interactive virtual interface is created that allows the user to temper with the different types of sensors, load and manage multiple data about the functionality of the household devices. The sensor management interface and the BIMs are all combined in a cooperative and open source platform that: a) presents each 3D building model and the 3D property areas (private and common) that it entails and their according semantic information, b) shows all the smart devices, fixtures and systems, c) gives the user the opportunity to interact with all the different types of sensors, their functionality, the data they collect, the data that they showcase and the duration of their operation, d) presents in a graphic manner the calculated energy consumption. This paper aims to boost neighborhood inclusion.

BIM, 3D cadastral data and AI for urban management - A case study for energy consumption monitoring

Dimitra ANDRITSOU, Christos ALEXIOU and Chryssy POTSIOU, Greece

1. OBJECTIVE OF THE RESEARCH

This paper is a part of a broader research of a PhD and series of projects that aim to compose a reliable, fast and public engaging methodology to develop a thorough, detailed, low – cost and interactive DT of a broader urban area in Greece by merging 3D cadastral instances with sustainable data. The purpose of this research is to construct a 4.0 virtual cadastral platform that combines AI and energy consumption, two prominent factors of the modern technological, social and fiscal world. The afore mentioned application combines the 3D depiction of property rights and spaces with the 4th dimension of time, as it entails AI – generated sensors that provide the models with a simulation of time based data. The proposed methodology does not afore field sensors as their exploitation requires budget or state funding. The methodology aims to offer an economical approachable solution for the joint availability of 3D land administration information and 4.0 energy consumption and cost estimation in one homogenous open source platform. This platform could support national land management portals, enrich cadastral systems, empower the sustainable functionality of urban neighborhoods and back up environmental policies for the operation of a building during its lifecycle.

By programming the sensors and using AI technology to produce simulative and dynamic data, this research aims to propose an innovative methodology for the current sensor management field. Most applications and researches implement field sensors in order to obtain real time environmental data of the physical world. Although the accuracy and performance of field sensors are much higher than AI – generated ones, the later offer some unique characteristics: 1) being highly customizable and thus ideal for applicable procedures, 2) offering qualitive and quantitive data and results that are satisfactory for 4.0 urban management and land administrative applications, 3) having no cost, 4)being able to generate data about different and varied environmental and sustainable parameters and 5) having a simple function that could be easily understood and supervised.

The proposed application combines into one consecutive and intuitive cloud based UI (User Interface): 1) a sensor management platform that the users can freely temper with the dynamic operation of the sensors, 2) statistical analyses and graphical representation of the energy consumption and operation of an entire building, a private space (apartment, loft) or a commonly used area (corridor, elevator, bunker or boiler room, entrance, penthouse), 3) estimated costs for the calculated energy consumption for the desired spatial extent, 4) scenarios and suggestions for cost savings and more sustainable management of the various devices, fixtures and systems inside and outside the building, 5) the 3D representation of the BIM of an old or new, real life, construction and the ability to virtually select objects and view useful information about them 6) the 3D volumetric representation of the various property areas that a complex multi – storey building entails, accompanied by semantic

inventories and lastly 7) the ability to fully view, navigate, manage and monitor the structural, and operational side of a real life building in an interactive and user friendly virtual environment.

The constructed methodology stresses out that no matter the state of funding and economical resources no neighborhood, nor building (old or new / publicly or privately owned / simple or complex / multi – storey or family house) should left behind in this age of digitization. As part of this research, school buildings and complex apartment buildings are virtually modelled, equipped with devices and interconnected with programmed sensors that feed them with AI generated dynamic and realistic data, according to their location, broader urban environment, architectural structure, characteristics and usage.

The research hopes to highlight the importance of upgrading the current cadastral systems and urban land management portals, to implement dynamic environmental, electronical, mechanical, plumbing and energy data while accompanying them with 3D prisms of RRR spaces. This could lead to not only reforming the current cadastral state from its 2D nature but also taking a step into the 4th (time), 5th (cost estimation) and 6th (sustainability) dimensions of urban and neighborhood land management.

The AI – generated sensors and the BIMs could support: 1) land administration incentives, 2) national sustainability frameworks and policies about limiting the urban energy consumption, 3) cost saving campaigns with rewards and motivations for the people, 4) crowdsourced geospatial hubs of neighborhoods for a more environmental friendly function of urban plots, 5) low – budget and reliable applications for energy monitoring and smart device management, 6) a DT of a complex building that can be remotely simulated and monitored through AI 7) 4.0, 5D and 6D smart cadastral applications.

The sensor handling and customization application is hosted on the cloud, being open and free of cost, thus promoting the importance of open source platforms and data. The code - generated sensors are interconnected with each building device in the BIMs providing to the user the capability of thoroughly tempering with the functionality, efficiency and expenditure of energy of each fixture of the according building. This way the devices and household systems gain intelligence, thus becoming smart. The devices belong to MEP (Mechanical, Engineering and Plumbing) and HVAC (Heating, Ventilation and Air Conditioning) categories. In the above mentioned categories devices such as control panels, gas stations, boilers, solar panels, intercoms, lighting, fire and protection alarms, energy and heating providing units, air cons etc. are included.

The proposed methodology combines AI technology and a highly interactive API with the 3D depiction of property spaces, for thoroughly monitoring and tracking the energy consumption of each household and even of every smart device in it. The sensor data can be managed through automated and programming procedures, while being highly customizable. The user can query, emit, add, edit, store and manage the above mentioned AI generated data stemming from the virtual sensors. The collected data can be utilized to construct scenarios and sustainable suggestions for a much more environmental friendly function of each property

space. This makes the proposal appropriate for optimal decision making on energy expenditure and environmental cost savings.

2. RELATED WORKS

Modern urban centers are characterized by their complex building structure, the coexistence of multiple overlapping functional systems, interconnected livelihood networks, multiple services, conflicting property rights and a vast number of detached operational devices, fixtures and hubs. A vision of the national scientific community is to be able to harmonize, compile and present all of the above mentioned singular entities in one homogenous virtual open sourced space that enables constant updates based on dynamic changes of the real environment. Basically an urban DT for land management and urban monitoring purposes has been set as the goal of many scientific sectors.

As it is thoroughly explained in literature, an IoT system is the cornerstone of such a technological reformation of an urban center and its various parts. In literature IoT systems are referred to as a wide network of interconnected self - arranged objects that constantly interchange various data in real – time thus creating a dynamic flow of information, analyzing and managing procedures for the most optimal function of industries and the deliverance of advantages in the social spectrum (Botta et al., 2016; Ghiaci et al., 2023). IoT is also mentioned as a technology that interconnects various instances with the Internet and thus communicating and exchanging information between the public and objects (Atzori, 2010).

Wireless Sensor Networks (WSN) offer real time data acquisition and access, a broad span being able to cover a big area, the ability to monitor for long – term periods and system scalability (Lanzolla et al., 2021). The new trend in the DT field of research affords the expansion of BIM technology and the development of other tools that can validly underpin data and information management processes for modification interventions (Desogus, et al., 2021). The compilation of IoT and BIM technologies has risen up as a promising and reliable proposal for the betterment of facility and building management (Dlesk, et al., 2023).

Nowadays, Circular Economy (CE) initiatives seem enticing for the European Union (EU) and the emerging economical systems, which center around the idea of increasing the efficiency of resources while diminishing at the same time the negative impact on the physical and natural environment (Askoxylakis et al., 2018; Patwa et al., 2021; Ghiaci et al., 2023). Of great importance is the combination of CE procedures with the IoT technology that can lead to utilization of energy to the fullest while boosting innovative and competitive ways amongst a variety of fields (Askoxylakis et al., 2018; Patwa et al., 2021; Ghiaci et al., 2023).
A crucial factor is the renovation of existing buildings structures in order to rank up in higher environmental classes and have an optimal functional efficiency. For that to be possible, some actions are needed such the construction of an information providing system, the establishment of legal protection and the provision of motivations for owners, etc. (European Commission, https://ec.europa.eu/energy/sites/ener/files/eu_renovation_wave_strategy.pdf).

The smooth, safe and sustainable function of a building construction is ensured if all the information and data on the household devices and the broader environment is being constantly tracked so that an efficient decision making is enabled in order to control emergencies (Kang, et al., 2018). Under specific circumstances the implementation of monitoring systems for parameters such as the temperature, humidity, etc. can be extremely helpful for the timely notification of the tenants / owners and for the control of the household devices (Kang, et al., 2018). IoT (Internet of Things) sensors are able to offer a wide variety of quantitive data that involve expenditure of energy and the internal state of an existing building construction that can empower energy modernizing procedures (Desogus, et al., 2021).

The combination of BIM and IoT could improve significantly the existing monitoring systems (Kang, et al., 2018). But the merge of the above mentioned technologies can present some challenges that need to be tackled, such as the fulfillment of a communicational route between the various sensors, the creation of a storing database of all the incoming information, the insertion of IoT sensor data into the BIM models and the establishment of an interactive interface between the user and the virtual system (Liu et al., 2017).

Applications on creating and implementing an operational complete WSN platform that can contribute in a variety of long – term environmental monitoring IoT procedures have been made (Lazarescu, 2014). Monitoring frameworks and prototypes utilizing both BIM and IoT technology have been constructed, exploiting microcontrollers with sensors for data collection and upload into a designed server. The sensors collect information about humidity, temperature and light intensity. The server processes, stores and presents the above mentioned information with BIM data (Kang, et al., 2018). Software that combines BIM, IoT and thermoregulatory behavior of the occupants of a building has been programmed (Kanna et al., 2022). The simulation of the energy consumption of a school building has been designed and tested, merging BIM, IoT data, GIS (Geographical Information Systems) and weather forecasting information (Bottaciolli et al., 2017).

A proprietary classification system for IoT sensors and actors and its implementation with BIM technology for the enhancement of facility management has been introduced (Dlesk et al., 2023). Also, a framework that combines BIM modeling and IoT networks for monitoring consumption and indoor conditions of existing building has been presented (Desogus et al., 2021). The proposed methodology utilizes AI technology for the programming, feed and function of the sensors. Implementing AI technology in 3D land administration and urban management applications is still a developing matter, with a lot of space for contribution and innovation. In literature, AI is described as the capability of a digital computer or a computer-controlled robot to take up, perform and complete tasks that are mostly thought to be executed by beings with intelligence (https://www.britannica.com/technology/artificial-intelligence). So, AI refers to the ability of a virtual / programmed project to develop systems correlated with the common intellectual processes that are characteristic of humans, such as reasoning, decision making, discovering meaning, generalizing information and learning from past experiences (https://www.britannica.com/technology/artificial-intelligence).

3. METHODOLOGY

3.1 Construction of BIMs

The first phase of the Methodology stage entails the creation of the 3D BIMs of the various types of buildings, existing and newly constructed, of the neighborhood. The creation of the BIMs is split between two separate phases, as different steps need to be made and varied information need to be gathered for the modelling of each type of building. For the new constructions the inner architectural plans are provided, so the building boundaries and their inner structure is known. Also, the plans entail the necessary geometrical, topographical and mathematical information for the modelling of all the different architectural elements such as walls, doors, windows, columns, etc. The BIMs are constructed following the methodology created and described in the research named "Merging BIM, Land Use and 2D Cadastral Maps into a Digital Twin Infrastructure" by Dimitra Andritsou, Sofia Soile and Chryssy Potsiou (2023), which is under publication.

3.1.1 BIMs of Existing Constructions



Figure 1. An existing building in the neighborhood under study in the Streetview Platform

Because an infrastructure that provides the inner topographical plans for the already existing buildings (Figure 1) has yet to be constructed by the state or other regulators, open and available data are used to obtain the needed information for constructing their external structure in 3D. So for the existing constructions the external casing of each building is modelled (Figure 2), creating a homogenous space for each floor without any inner classification of rooms (Figure 3).



Figure 2. BIMs of the old constructions



Figure 3. The modelling of the inner structure as a homogenous space

3.1.2 BIMs of the new constructions

The second phase involves the creation of BIMs for the new constructions (Figure 4). The BIMs of the new constructions are modelled following the provided inner 2D architectural, floor and topographical plans. Following the standardization of the given plans, the exact and accurate dimensions of the various architectural elements are provided. So for the new constructions each building entails a detailed structural classification of each inner space and room (Figure 5).

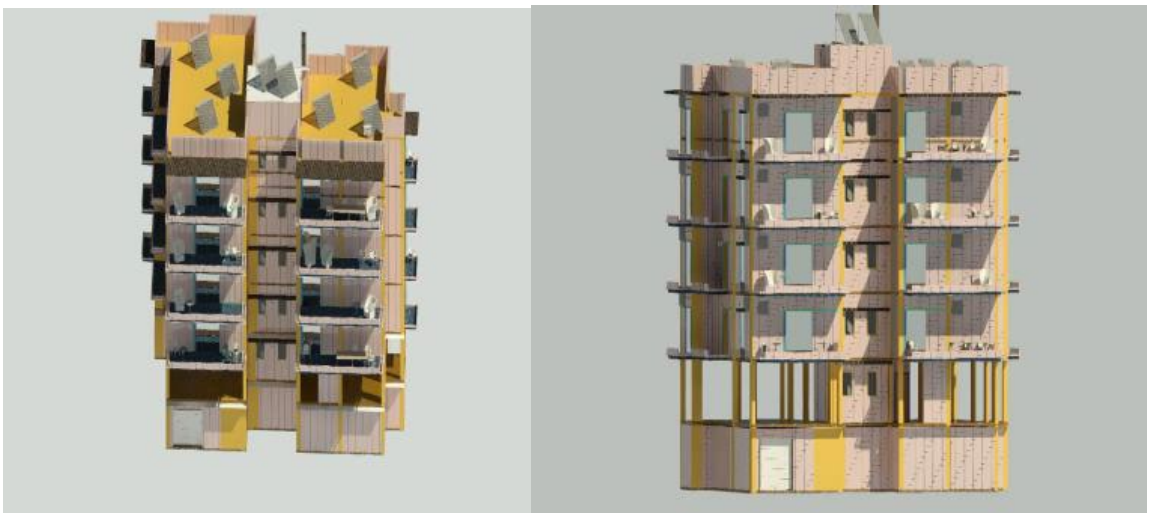


Figure 4. A BIM of a new construction



Figure 5. The classification of the inner property spaces, apartments and common area

3.1.3 Textures and Materials of all BIMs

For all the BIMs unique textures and singular materials are crafted for the realistic and accurate virtual reconstruction of the buildings (Figure 6).



Figure 6. Singular and unique textures and materials are crafted for each BIM, old (left) and new (right)

3.1.4 3D RRR spaces and Volumetric Prisms of Properties

For both BIMs, of existing and newly made constructions, the various RRR (Rights, Responsibilities and Restrictions) spaces are modelled as 3D volumetric prisms, presenting the different legal properties in and outside of each building. The buildings have different private and common areas. For the existing constructions the private spaces in each floor level are lofts (Figure 7), while for the newly constructed buildings the apartments (Figure 8) represent the private legal rights. The lofts, apartments and all the rest of the property spaces are modelled as 3D volumetric prisms.

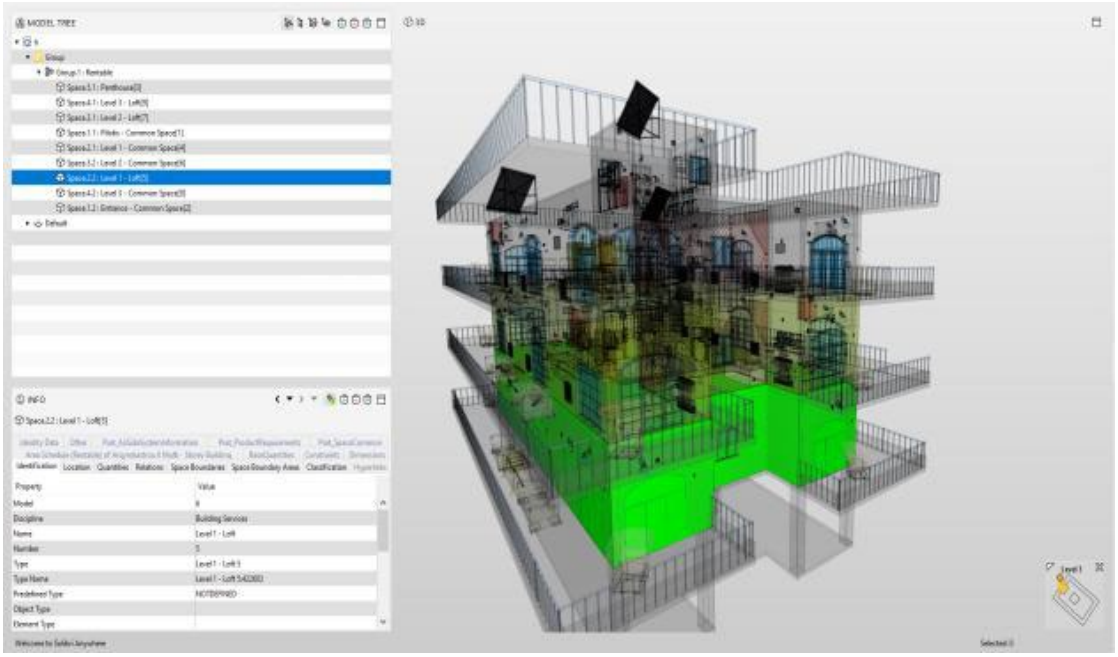


Figure 7. Example of a Loft shown as a 3D volumetric prism in the Solibri by Nemetschek

In the private area category are considered to belong the: 1) Apartments, 2) Lofts, Appurtances (External Parking Spaces) 4) Internal Parking Spaces and 5) Storages – Storage Rooms.

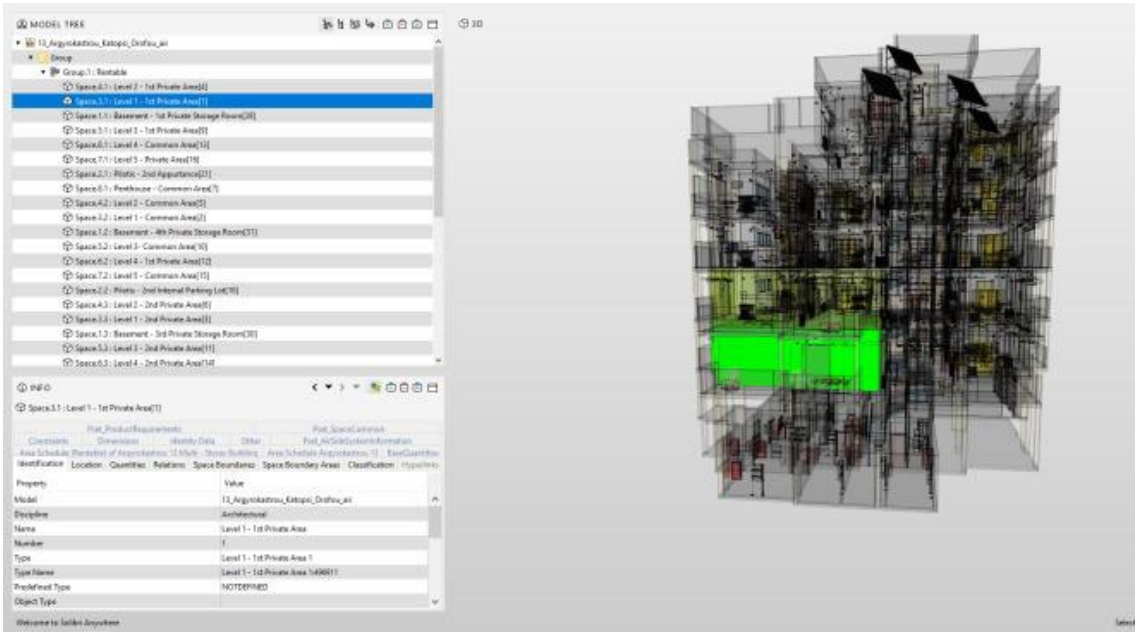


Figure 8. Private Area of an Apartment in the Solibri by Nemetschek

In the common area category belong the following areas: 1) Corridors, Stairs and Elevators, 2) Boiler – Bunker Rooms, 3) Commonly used Storages ,4) Building Entrances, 5) Penthouses and 6) The external area of each Pilotis. Each property volume is modelled following the 2D boundaries of the architectural plans as a volumetric prism. For each building a Schedule containing semantic and geometrical information about each space is structured. The semantic tables include information about the various properties such as the Name, Level, Type, Ifc Extraction Type, calculated Area and Perimeter, etc. (Figure 9).

<Area Schedule (Rentable) of Argyrokastrou 11 Multi - Storey Building>

A	B	C	D	E	F	G	H	I	J
Name	Area Type	Comments	Level	Export to IFC	Export to IFC As	IFC Predefined Type	Area	Perimeter	Number
Level 1 - 1st Private Area	Floor Area	Apartment	Level 1	Yes	IfcSpace	INTERNAL	128 m²	53	1
Level 1 - Common Area	Building Common Area	Corridor, Elevator and Stairs	Level 1	Yes	IfcSpace	INTERNAL	15 m²	18	2
Level 1 - 2nd Private Area	Floor Area	Apartment	Level 1	Yes	IfcSpace	INTERNAL	104 m²	48	3
Level 2 - 1st Private Area	Floor Area	Apartment	Level 2	Yes	IfcSpace	INTERNAL	128 m²	54	4
Level 2 - Common Area	Building Common Area	Corridor, Elevator and Stairs	Level 2	Yes	IfcSpace	INTERNAL	15 m²	18	5
Level 2 - 2nd Private Area	Floor Area	Apartment	Level 2	Yes	IfcSpace	INTERNAL	104 m²	48	6
Level 3 - 1st Private Area	Floor Area	Apartment	Level 3	Yes	IfcSpace	INTERNAL	128 m²	53	7
Level 3 - Common Area	Building Common Area	Corridor, Elevator and Stairs	Level 3	Yes	IfcSpace	INTERNAL	15 m²	18	8
Level 3 - 2nd Private Area	Floor Area	Apartment	Level 3	Yes	IfcSpace	INTERNAL	104 m²	48	9
Level 4 - 1st Private Area	Floor Area	Apartment	Level 4	Yes	IfcSpace	INTERNAL	128 m²	53	10
Level 4 - Common Area	Building Common Area	Corridor, Elevator and Stairs	Level 4	Yes	IfcSpace	INTERNAL	15 m²	18	11
Level 4 - 2nd Private Area	Floor Area	Apartment	Level 4	Yes	IfcSpace	INTERNAL	104 m²	48	12
Penthouse - Common Area	Building Common Area	Penthouse	Penthouse	Yes	IfcSpace	INTERNAL	24 m²	21	13
Pilotis - Common Area	Building Common Area	Entrance	Pilotis	Yes	IfcSpace	INTERNAL	30 m²	23	14
Pilotis - 1st Appurtance	Floor Area	External Private Parking Lot	Pilotis	Yes	IfcSpace	PARKING	12 m²	14	15
Pilotis - 2nd Appurtance	Floor Area	External Private Parking Lot	Pilotis	Yes	IfcSpace	PARKING	12 m²	14	16
Pilotis - 3rd Appurtance	Floor Area	External Private Parking Lot	Pilotis	Yes	IfcSpace	PARKING	12 m²	14	17
Pilotis - 4th Appurtance	Floor Area	External Private Parking Lot	Pilotis	Yes	IfcSpace	PARKING	18 m²	19	18
Pilotis - 5th Appurtance	Floor Area	External Private Parking Lot	Pilotis	Yes	IfcSpace	PARKING	12 m²	14	19
Pilotis - 6th Appurtance	Floor Area	External Private Parking Lot	Pilotis	Yes	IfcSpace	PARKING	12 m²	14	20
Basement - 1st Private Storage Roo	Floor Area	Private Storage Area	Basement	Yes	IfcSpace	INTERNAL	22 m²	19	21
Basement - 2nd Private Storage Roo	Floor Area	Private Storage Area	Basement	Yes	IfcSpace	INTERNAL	11 m²	14	22
Basement - 1st Underground Private	Floor Area	Underground Internal Parking Lot	Basement	Yes	IfcSpace	INTERNAL	13 m²	18	23
Basement - 2nd Underground Private	Floor Area	Underground Internal Parking Lot	Basement	Yes	IfcSpace	INTERNAL	20 m²	19	24
Basement - 10th Private Storage Ro	Floor Area	Private Storage Area	Basement	Yes	IfcSpace	INTERNAL	6 m²	10	25
Basement - 9th Private Storage Roo	Floor Area	Private Storage Area	Basement	Yes	IfcSpace	INTERNAL	6 m²	10	26
Basement - 8th Private Storage Roo	Floor Area	Private Storage Area	Basement	Yes	IfcSpace	INTERNAL	8 m²	11	27
Basement - 7th Private Storage Roo	Floor Area	Private Storage Area	Basement	Yes	IfcSpace	INTERNAL	10 m²	15	28
Basement - 3rd Private Storage Roo	Floor Area	Private Storage Area	Basement	Yes	IfcSpace	INTERNAL	9 m²	13	29
Basement - 4th Private Storage Roo	Floor Area	Private Storage Area	Basement	Yes	IfcSpace	INTERNAL	9 m²	12	30
Basement - 5th Private Storage Roo	Floor Area	Private Storage Area	Basement	Yes	IfcSpace	INTERNAL	5 m²	11	31
Basement - 6th Private Storage Roo	Floor Area	Private Storage Area	Basement	Yes	IfcSpace	INTERNAL	15 m²	16	32
Basement - Common Area	Building Common Area	Corridor, Stairs, Boiler Room, Co	Basement	Yes	IfcSpace	INTERNAL	111 m²	124	33

Figure 9. Information Table with semantic and geometrical data about each volumetric property

There are only two public building structures, these of a Primary School (Figure 10) and a Nursery (Figure 11).



Figure 10. The Primary School in the Revit Software



Figure 11. The Nursery as modelled in the Revit program

3.1.5 Equipment and Manning of the BIMs with internal and external devices

Each BIM is equipped, internally and externally, with devices, fixtures and systems of different functionality and operation (Figure 12).

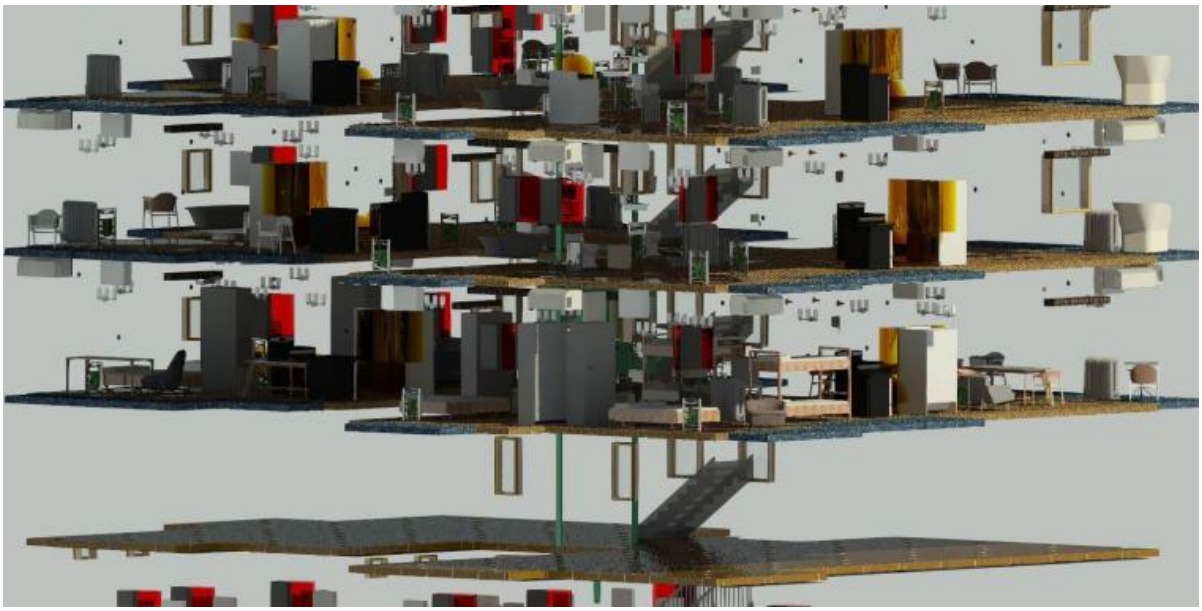


Figure 12. The various internal and external devices, fixtures and systems of the MEP and HVAC category

The choice and placement of all the various functional devices is made to maximize the verisimilitude and fidelity of the buildings' virtual simulations (Figure 13).



Figure 13. MEP, HVAC and furniture inside and outside a building structure

The devices, fixtures and systems (Figure 14) are classified into 2 major categories as it is already mentioned: 1) MEP (Mechanical, Electrical and Plumbing): electrical and mechanical control panels, fire and protection alarms, intercoms, toilets, bathtubs, sinks, refrigerators, stoves, washing machines, lightings, computers, displays, etc. and 2) HVAC (Heating, Ventilation and Air Conditioning): water heater tanks, boilers, air-conditioning units, heaters, gas providers, energy providing units, etc.



Figure 14. MEP elements (electrical and mechanical control panels) and HVAC elements (gas and energy providing units)

Furniture are also added to each room (Figure 15) of each building, making it more lifelike (Figure 16).

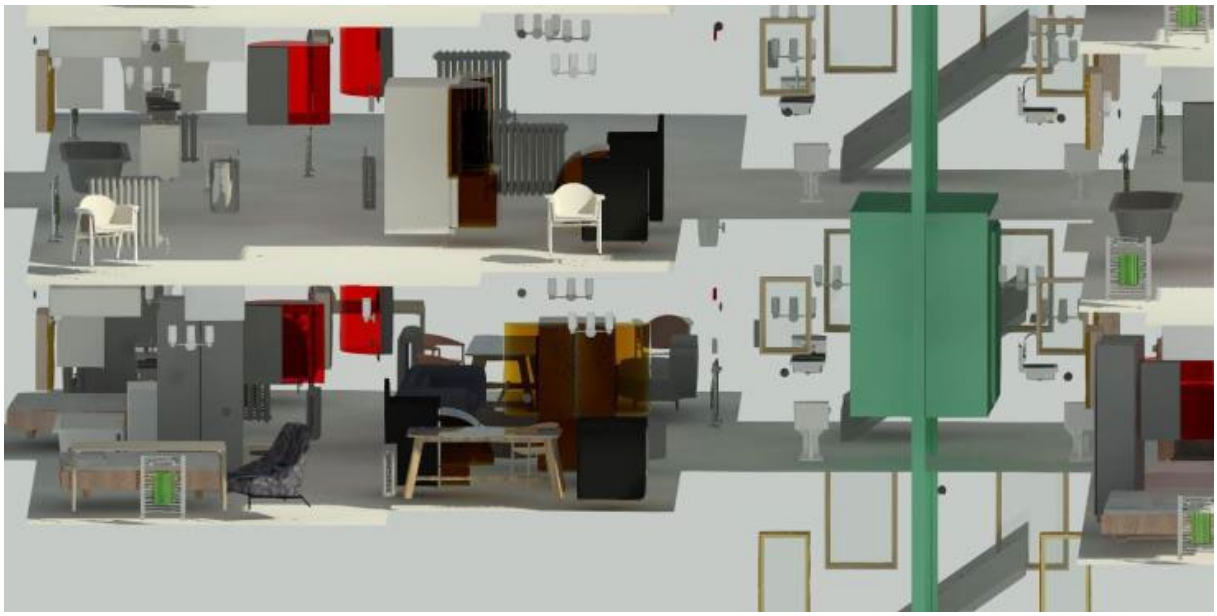


Figure 15. Furniture, electrical, mechanical, plumbing, heating fixtures and an elevator

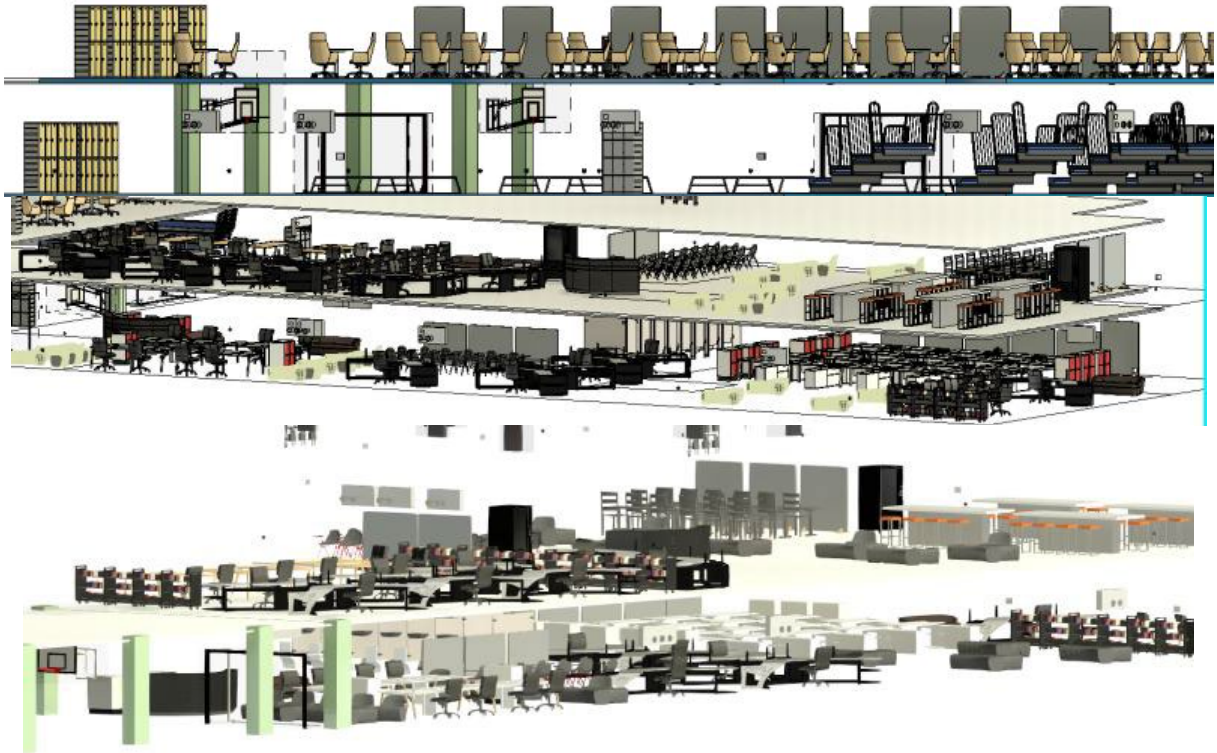


Figure 16. The inner equipment and furniture of the Primary School Building, classrooms, offices and gymnasium

3.1.7 Extraction of the BIMs as IFC files

All the BIMs are extracted from Revit as IFC files in order to be converted into JSON format, read and parsed by the programming code and consequently interconnected with the Sensor Management platform. The IFC files carry all the desired 3D geospatial, semantic and textural information from the Revit software to the final cloud base platform.

3.2 Programming of Sensor Management Platform

The system is designed to be a multi-faceted solution for urban planning agencies and cadastral services worldwide. The first component focuses on parsing and managing data from real-world IoT sensors and devices, storing time series data, and providing actionable insights through machine learning algorithms. The second component is geared towards simulating large IoT networks by generating synthetic time series sensor data. Both components are equipped with their APIs and web interfaces for comprehensive user engagement.

3.2.1 Technical Stack

- Python 3.11: Core programming language for backend services.
- IfcOpenShell: Library for parsing IFC files containing 3D models and sensor metadata.
- Three.js: JavaScript library for rendering 3D models on the web interface.
- TimeGAN: Generative Adversarial Networks for generating synthetic time-series data.
- MongoDB: NoSQL database for storing time series data and sensor information.

3.2.2 System Architecture of Component 1 (Energy Management and Optimization System)

1. IoT Data Parser
    a. Receives data from various IoT sensors like AC units, smart fridges, and other smart devices.
    b. Implemented in an interpreted programming language.
2. Database
    a. Stores the time series data being scraped from IoT sensors.
    b. Also stores parsed IFC model data, including metadata about IoT sensors.
3. IFC File Parser (IfcOpenShell)
    a. Accepts IFC 3D models uploaded by users.
    b. Parses the models and stores their information in the Database.
4. Web Interface
    a. Enables users to interact with the 3D models and sensor data.
    b. Uses WebGL web standard to render 3D models in a browser environment.
5. Machine Learning Models
    a. Includes Data Preprocessing and Feature Engineering, Anomaly Detection, Forecasting and Decision Trees.
    b. Provides recommendations to users on cost-cutting measures.

3.2.3 Workflow of Component 1 (Energy Management and Optimization System)

- Users can upload IFC 3D models which are parsed using IfcOpenShell and stored in the Database.
- IoT sensors specified in the IFC files are automatically registered for data scraping.
- Time series data from IoT sensors are stored in the Database.

- Users can interact with 3D models and sensor data through a web interface built with WebGL.
- The machine learning algorithms analyze the stored data to provide actionable insights.

3.2.4 APIs of Component 1 (Energy Management and Optimization System)
- Data API: Allows for the retrieval and storage of IoT data.
- Model API: Handles IFC file uploads and parsing.
- Analytics API: Exposes machine learning models for data analysis.

3.2.5 Communication Framework of Component 1 (Energy Management and Optimization System)
- Internal: RESTful APIs for internal communication between sub-components.
- External: Web interface for user interaction.

3.2.6 System Architecture of Component 2 (Synthetic IoT Sensor Network Generator)
1. Synthetic Sensor Generator
    a. Utilizes TimeGAN to generate synthetic IoT sensor data with specific characteristics.
    b. Implemented in an interpreted programming language.
2. Web Interface
    a. Allows users to configure the type and number of synthetic sensors.

3.2.7 Workflow of Component 2 (Synthetic IoT Sensor Network Generator)
- Users configure the synthetic IoT network via the web interface.
- TimeGAN generates time series data for each synthetic sensor.

3.2.8 APIs of Component 2 (Synthetic IoT Sensor Network Generator)
- Generation API: Allows for the configuration and initiation of synthetic sensor generation.

3.2.9 Communication of Component 2 (Synthetic IoT Sensor Network Generator)
- Internal: RESTful APIs for internal communication between sub-components.
- External: Web interface for user interaction and API for data retrieval by Component 1.

3.2.10 Inter-Component Communication
Component 1 can reach out to the synthetic sensors created by Component 2 through their respective APIs, effectively simulating real-world scenarios without relying on physical infrastructure.

3.3 Architecture Diagram
Below the architectural diagram is presented (Figure 17)

3.3.1 Architecture Diagram Legend
- Nodes in sky blue represent the sub-components of the first component focused on "Energy Management and Optimization."

- Nodes in light green represent the sub-components of the second component, which is the "Synthetic IoT Sensor Network Generator."
- The gray arrows indicate the flow of data or control between sub-components or between the two main components.

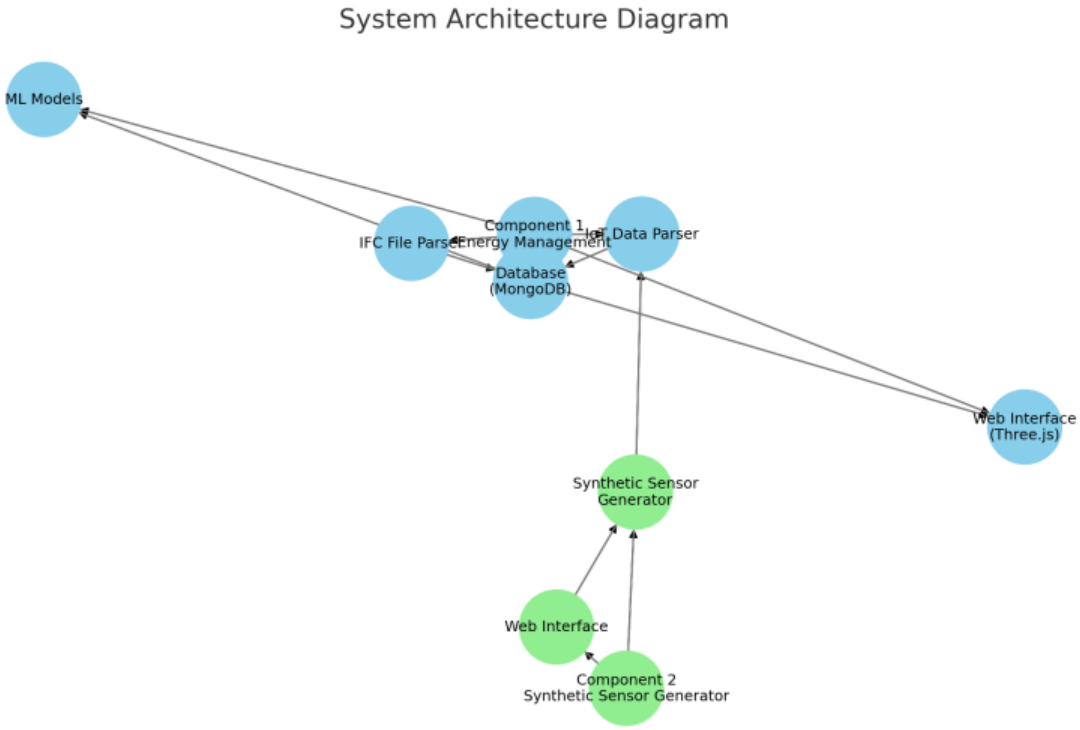


Figure 17. The inner equipment and furniture of the Primary School Building, classrooms, offices and gymnasium

3.4 Notion of System Design

The innovative dual-system architecture proposed in this research offers a groundbreaking approach to the complexities of managing urban and cadastral data. At its core, the system leverages real-time IoT sensor data alongside machine-generated synthetic data, enabling comprehensive, data-driven decision-making without the constraints of traditional infrastructure. The integration of IfcOpenShell for parsing IFC 3D models allows the platform to seamlessly incorporate building information modeling (BIM) data, a cornerstone in modern cadastral management. This adds a spatial dimension to the sensor data, enhancing the granularity and contextual understanding of energy usage patterns within buildings. The machine learning models, integrated into the first component, offer analytics capabilities ranging from anomaly detection to cost-cutting recommendations, thus providing actionable insights that can significantly improve cadastral services by optimizing energy management and reducing operational costs. Additionally, the system's cloud-based MongoDB database ensures high scalability and availability, making it apt for managing large-scale, dynamic urban environments. By merging real-world sensor data, synthetic data, 3D spatial models, and machine learning analytics into a single, cloud-based platform, this system introduces a new paradigm in the effective management of cadastral data.

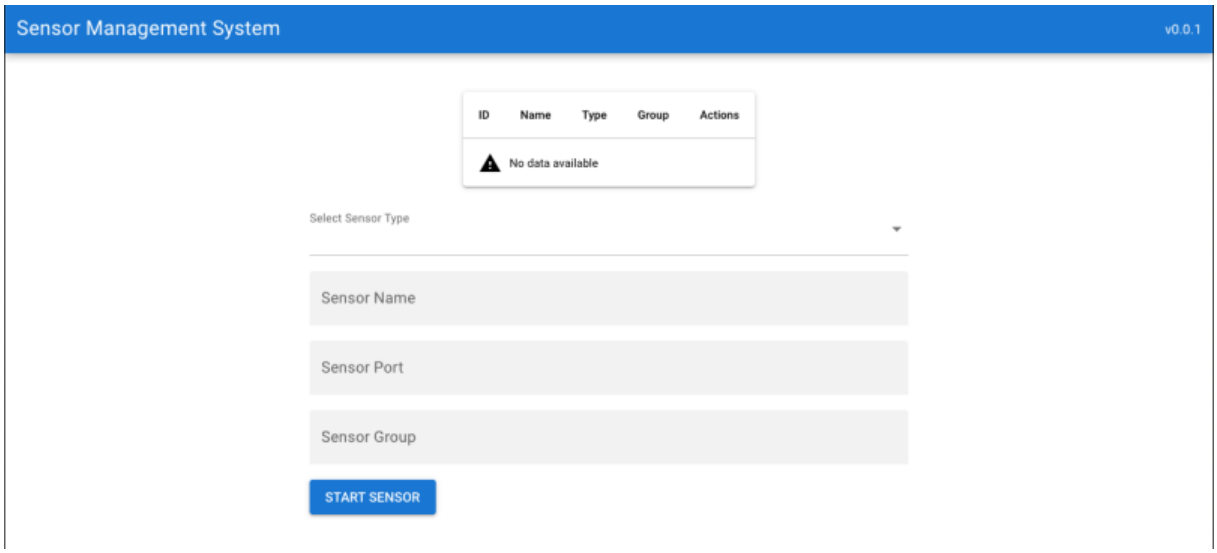
3.5 Potential

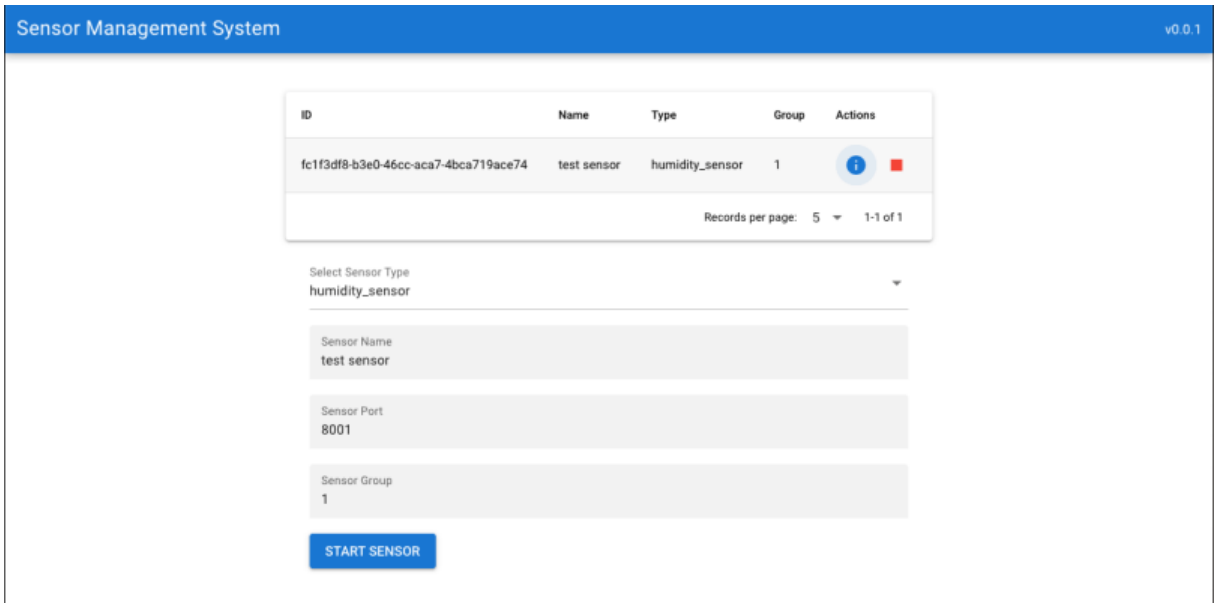
The framework is designed to be modular, allowing for future expansions and adaptations to meet evolving demands and technologies.

- Incorporating more types of machine learning models for enhanced analytics.
- Enabling real-time analytics and alerts for immediate decision-making.

3.6 Interface

Below the sensor management platform is presented, in which the user can interact with the AI generated environmental data of each mechanical, electrical, plumbing, heating and venting device (Figure 18).





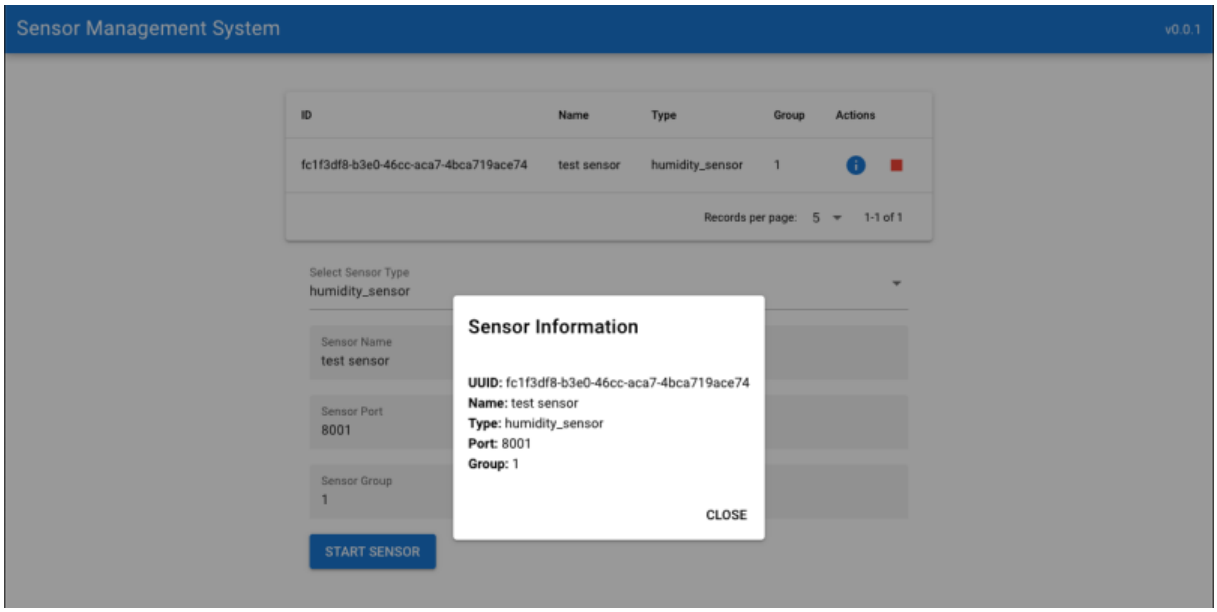


Figure 18. The mock sensor management platform

Lastly, the final user interface of the platform is presented. In the platform the user can interact with all the various architectural, structural and spatial components of each building and obtain legal and environmental information for each one of them. The entire hierarchical tree of the IFC format is available for the user to study and manage (Figure 19). All the spatial and semantic information that is modeled in Revit, is presented thoroughly and graphically in the constructed platform.

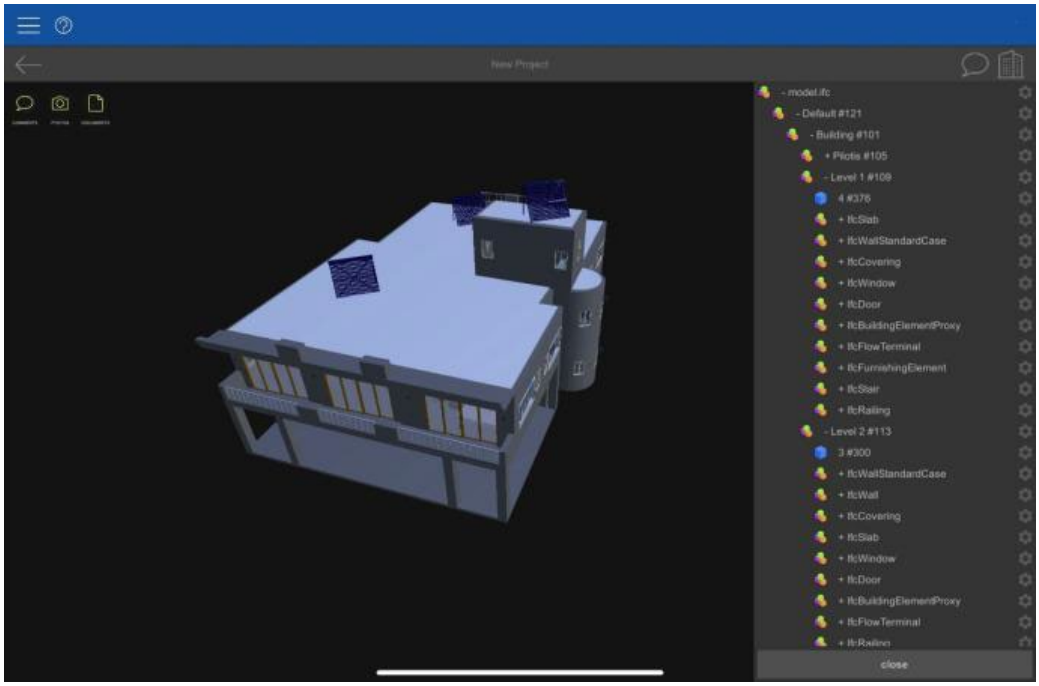


Figure 19. The entire IFC schema and all its spatial and semantic instances

The user can view the various property areas as 3D prisms or calculate the estimated maximum or minimum energy consumption of a device, fixture or system. For example, as it is shown in Figure 20 the user can add and acquire information about a solar panel while the object can also be hidden in view if it is desired by the user.

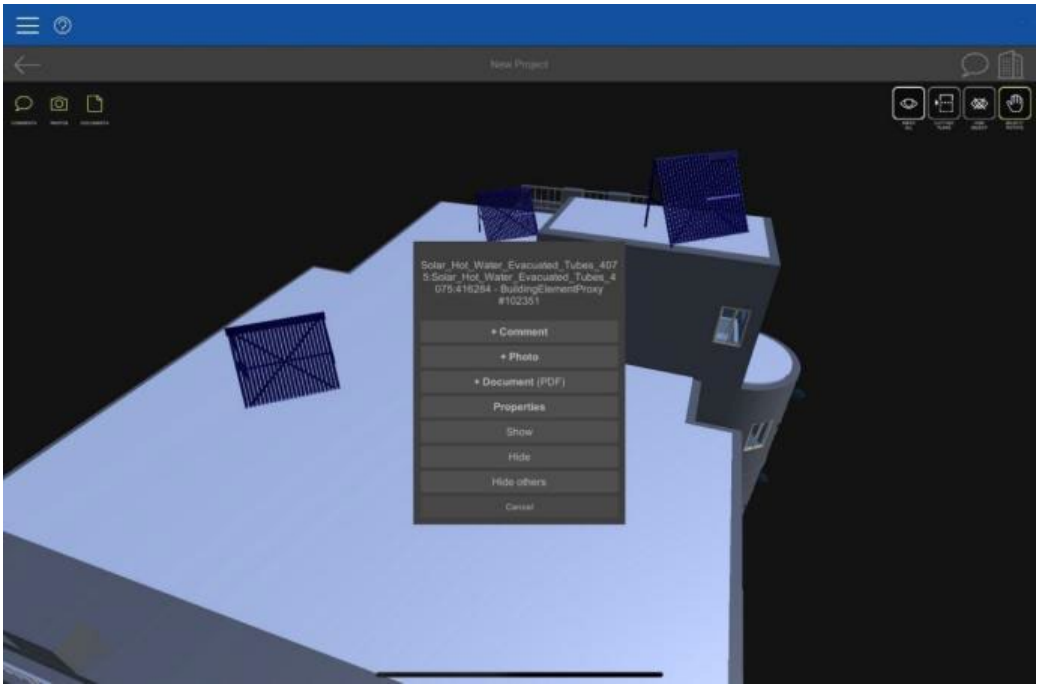


Figure 20. The information tab about a solar panel unit

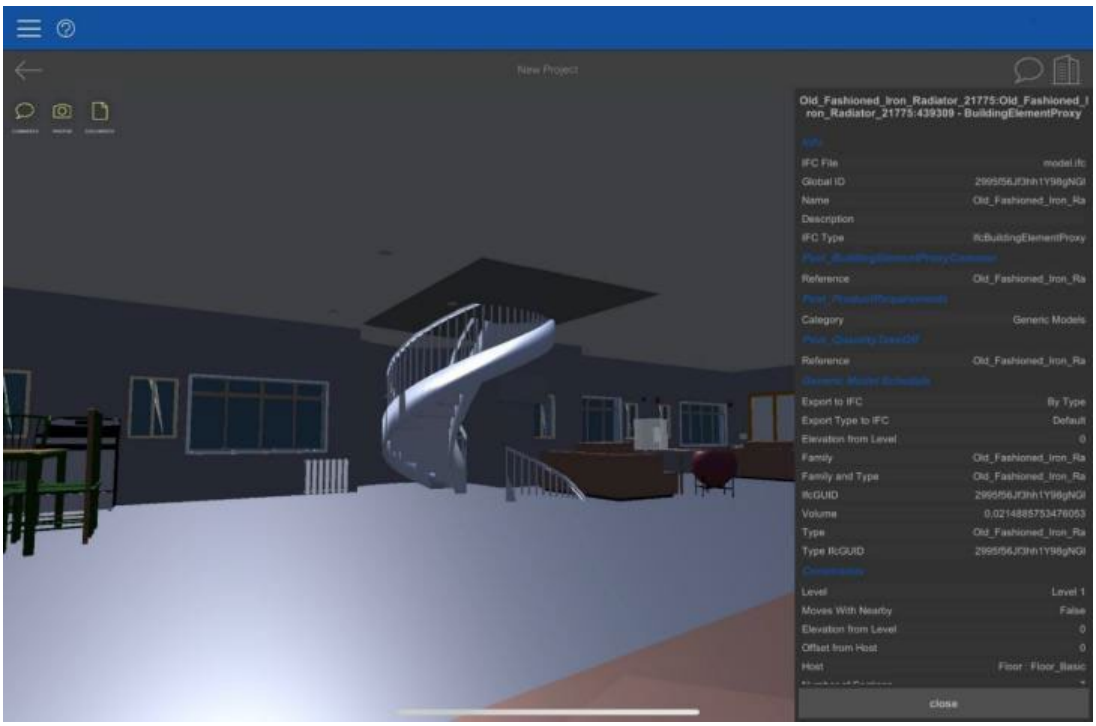


Figure 21. Geometrical, functional and semantic information about a heat providing radiator device

The user can navigate virtually through the internal space of each building and room (Figure 21) thus being able to observe, manage and interact with their various components (Figure 22). This gives the user a sense of immersion and engagement.
All in all, the user can acquire information about:

- ✓ the Family, Category and IFC Type of an object,
- ✓ the dimensions, such as the calculated area and volume of a spatial element,
- ✓ the spatial constraints of an object, such the level,
- ✓ the function and operation of all the external and internal devices, fixtures and systems of a building or room during the course of a day,
- ✓ the sustainability levels and energy consumption progression of an RRR space,
- ✓ the inner and outer structure and architecture of an existing or new building, etc.

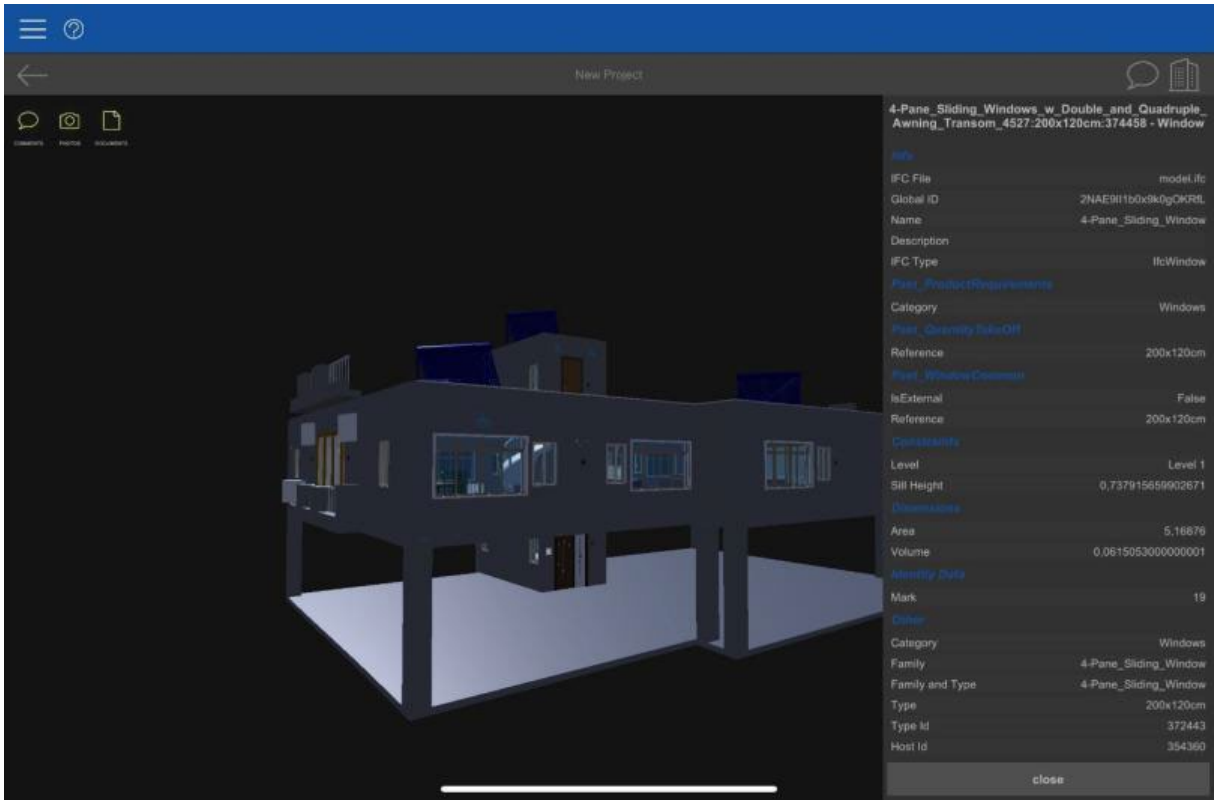


Figure 22. Geometrical, functional and semantic information about a sliding window panel

4. CASE STUDY

4.1 Area Under Study

Thea area under study comprises of all the buildings that are entailed in 3 different City Blocks in the urban neighborhood of Chalandri, Athens in Greece.

The research is centered around 9 in total differently structured building constructions, existing and new (Figure 23). The most prominent land use of the area under study is housing, while the vast majority of the buildings are of private ownership (Figure 24).



Figure 23. The 9 different building constructions, old and new



Figure 24. The prominent land use in the neighborhood is housing

Only two building structures present a different land usage and legal status. There are two educational public buildings amongst the studying area, one Primary School (Figure 25) and one Nursery (Figure 26).



Figure 25. The Primary School located in the neighborhood



Figure 26. The Nursery in the neighborhood

The area is characterized by an orderly, clear and spacious structuring and segmentation of the various buildings. There are no signs of urban sprawl nor arbitrary constructions.

5. DISCUSSIONS AND CONCLUSIONS

The proposed methodology combines BIM technology with AI generated data, providing a fresh perspective on data merging. The final platforms offer a simulative 4.0 environmental and cadaster application for sustainable decision making, cost management, betterment of efficiency of buildings, urban monitoring and land administration purposes. By providing an open source, interactive and user friendly interface the platform is a proposal for a free, interoperable and engaging virtual environment for storing all the important information about a building, apartment or room in 3D and graphical format. By combining time based sensor data about each device, fixture and system with the visualization of 3D property rights as prisms, the platform entails a solution for storing cadastral and operational information, all in an accessible virtual hub.

The AI generated data from the sensors are highly customizable, while being simulative of each buildings' real function in the span of 24 hours. The users can view their respective properties as 3D volumes and acquire vital environmental and economic information about them that could lead to the optimization of everyday life, while being in harmony with the external and internal environment. The platform combines 3 dimensions: 1) time, 2) cost and 3) sustainability. The cloud base platform can contribute to: 1) 3D and 4.0 cadaster applications, 2) crowdsourced building and device management, 3) environmental and sustainability frameworks and incentives, 4) land management and establishment procedures, 5) the creation of urban virtual twins, 6) the monitoring of the facilities of building, 7) facility coordination applications, 8) optimal and sustainable decision making, 9) scenario crafting and prediction making.

As a future enrichment the platform can be merged with a cadastral database in .xml format, simulating the official and regulatory cadastral entities and framework and thus providing a much more extended version of a 4.0 cadastral registry, land administration and management. The various spaces can be depicted with different degraded colors, visualizing the swift in energy consumption and operation of devices / machines / fixtures and systems. The platform could also host graphical and mathematical representations (charts, pies and graphs) of the progression of the costings and energy consumption of a household. The platform could also present a "leaderboard" with the different environmental efficiency "scores" of the tenants, thus providing motivations for a more prudent, sustainable and environmental friendly energy consumption and operation of each property area.

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BIOGRAPHICAL NOTES

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Leveraging BIM for the LADM Part 4 - Valuation Information Model: the case study of Cyprus

Pavlos DEMETRIADES (Cyprus), Eftychia KALOGIANNI (The Netherlands) and Efi DIMOPOULOU (Greece)

Key words: Building Information Model (BIM), Land Administration Systems (LAS), Land Administration Domain Model (LADM), Valuation Information Model, data interoperability, data circularity, property valuation

SUMMARY

Building Information Model (BIM) is a powerful tool for managing and utilizing data throughout the lifecycle of buildings and infrastructure. This paper explores the options, and considerations, of using BIM data for the Land Administration (LA) domain. The ISO19152 Land Administration Domain Model (LADM), as a widely recognized international standard for Land Administration domain, is currently undergoing revision. The new Edition will be multipart, with 6 Parts, including Part 4 (ISO19152-4) about Valuation Information, specifying the characteristics and semantics of valuation registries maintained by public authorities. This valuation part may include incorporating advancements in the representation and management of property-related information, as well as aligning with the architecture, engineering, and construction (AEC) industry. BIM has a significant impact on the AEC industry, since its adoption transforms traditional processes, enhancing among others, visualization, lifecycle management and facility operation. By integrating information from BIM models into the LADM Part 4, several benefits can be achieved, such as: more accurate 3D property representation, dynamic and realistic assessment of property value, automation of valuation processes and compliance with industry regulations. Therefore, this paper investigates how to integrate BIM data with the LADM, particularly in the context of Cyprus. The mapping between the existing Valuation Model of Cyprus and the basic concepts of LADM Part 4 takes place and a proposed valuation information model for Cyprus based on LADM Part 4 is designed. This model is further enriched by the integration of data derived from a real-world mixed-use buildings. Additionally, we presented the primary objective of this paper along with its significance within the context of the Cyprus Land Registry system, with particular focus on its relevance to the Valuation Department.

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1 INTRODUCTION

Cities have undergone rapid expansion, evolving into larger, denser, and more complex due to continuous population growth and the need for efficient use of limited space (Dimopoulou, 2015). Urban areas often feature intricate constructions both above and below the surface. This global trend has given rise to new demands for sustainable land development to preserve and protect property. To meet this objective, continuous and accurate information about land ownership, rights, restrictions, and responsibilities, in conjunction with its valuation and utilization is indispensable.

In this scene, Land Administration Systems (LAS) serve as the foundational framework for managing land information, facilitating land tenure procedures, as well as registration, and transaction processes (Oguzhan Mete et al., 2022). The Land Administration Domain Model (LADM) has emerged as an international standard (ISO 19152:2012) to foster efficient interoperability, communication, and data exchange among various land administration systems.

Although the LADM Edition I is extensively used (Kalogianni et al., 2021) and is applicable for various use cases and purposes, ISO rules prescribe periodic revision (Lemmen et al., 2023) and therefore, the revision of the standard is currently ongoing. LADM Edition II is being developed as multi-part, with 6 parts, covering a wider scope of land administration (Kara et al., 2023). One of those, LADM Part 4: Valuation Information, specifies the characteristics and semantics of valuation registries maintained by public authorities and to reveal the interrelations between valuation registries and other land administration registries (Kara et al., 2021).

On the other hand, much is going in the Architecture, Engineering, Construction, Owner Operator (AECOO) sector and its modernisation, with Building Information Model (BIM) and specifically Industry Foundation Class (IFC) playing an important role. These standards, LADM and IFC, are vital to achieving communication and interoperability between AEC and LAS sector.

In Cyprus, the valuation of immovable property plays a pivotal role in the dynamic landscape of land development. With its strategic location and stunning natural beauty, Cyprus has become an attractive destination for real estate investment. Investors and developers rely on meticulous property valuations to make informed decisions about their ventures. The

valuation process ensures that the potential of each piece of land is accurately assessed, considering its unique characteristics and development prospects. As the demand for land development projects continues to rise, a precise understanding of immovable property valuation in Cyprus remains essential for sustainable and profitable ventures in this flourishing real estate market.

The scope of this paper is the optimization of the valuation procedure of the immovable property in the context of the land administration systems, using international standards like BIM/IFC and LADM-Part4. At the same time, another scope is the implementation of the valuation model of Cyprus, based on the LADM – Part 4, and the implementation of valuation information in a BIM/IFC.

The rest of the paper is structured as follows: first the background information is presented in Section 2. In Section 3 the methodological framework for the development of the valuation information model for Cyprus based on ISO19152-4 is presented, including the current valuation model of Cyprus and the detailed presentation of the modelling procedure. Following, the paper demonstrates the integration of valuation information in an IFC model based on the proposed Valuation Model of Cyprus which developed in Section 3, and visualises this information based on IFC's entities. Lastly, Section 5 presents final conclusions and Recommendations.

2 BACKGROUND INFORMATION

This Section provides all the necessary background information crucial to understanding the objective of this paper. The Land Administration Domain Model is one of the key concepts analysed at this paper and the current developments of the second edition of the standard are introduced, focusing on Part 4, which addresses valuation information. Moreover, the significance of BIM/ IFC for Land Administration Systems and property valuation applications is highlighted, while developments and innovations in this filed are also presented.

2.1 ISO 19152 Editions and ISO19152-4: Valuation Information

The first version of the Land Administration Domain Model (LADM) was adopted as an international standard by the International Organization for Standardization (ISO) in 2012, making it the most significant standardization in the field of land administration systems to date at the international level (Dimopoulou E., 2015). The main objective of LADM is to organize information about rights, restrictions, and responsibilities (RRRs) attached to land (including the space below and above it), as well as their geometric characteristics (ISO, 2012). This facilitates communication between involved organizations and systems within a country or between different countries through a common terminology (Lemmen et al., 2015).

2.1.1 ISO 19152 Edition II

All standards issued by the ISO Organization are subject to a revision process at regular intervals. In this context, the LADM revision process started in 2019 and is currently ongoing, with the second edition of the standard now having 6 parts under development, as the range of

information modelling it will cover is wider than that of the first edition (Kalogianni et al., 2023). The development of these parts is carried out by the LADM committee (LADM Editors), which are discussed and evaluated by the participants in ISO Technical Committee ISO/TC 211, Geographical information/Geomatics. To date, the first five parts are under development, following the ISO revision process, while the sixth is expected to be developed in close collaboration between ISO and the Open Geospatial Consortium (OGC) in the near future. The standardization process by the ISO follows several stages and votes, until a candidate standard is voted as an international standard. To date, none of the 5 -under-development-parts of ISO19152 Edition 2 has been voted as an international standard, while ISO19152-1: Generic Conceptual Model is expected to be the first to be voted within 2024 (Lemmen et al., 2021).

The following figure shows the six parts of the second edition of the LADM. It is noted that the first five concern conceptual models (Kara et al., 2023).

1. Part 1 – Fundamentals: will form the core of the new standard supporting the rest of the parts, defining the basic concepts, packages and interrelationships.
2. Part 2 – Land Registration: will include in detail all information for recording information in land management systems.
3. Part 3 – Marine Space Georegulation: based on the concepts of Part 1 it will concern the modeling of information about marine space.
4. Part 4 – Valuation Information: based on Part 1 & Part 2 will concern the modelling of the information related to the valuation of land values.
5. Part 5 – Spatial Plan Information: based on Part 1 & Part 2 will concern the modelling of the information related to spatial planning.
6. Part 6 – Implementations: alternative technical implementations of the above parts will be developed.

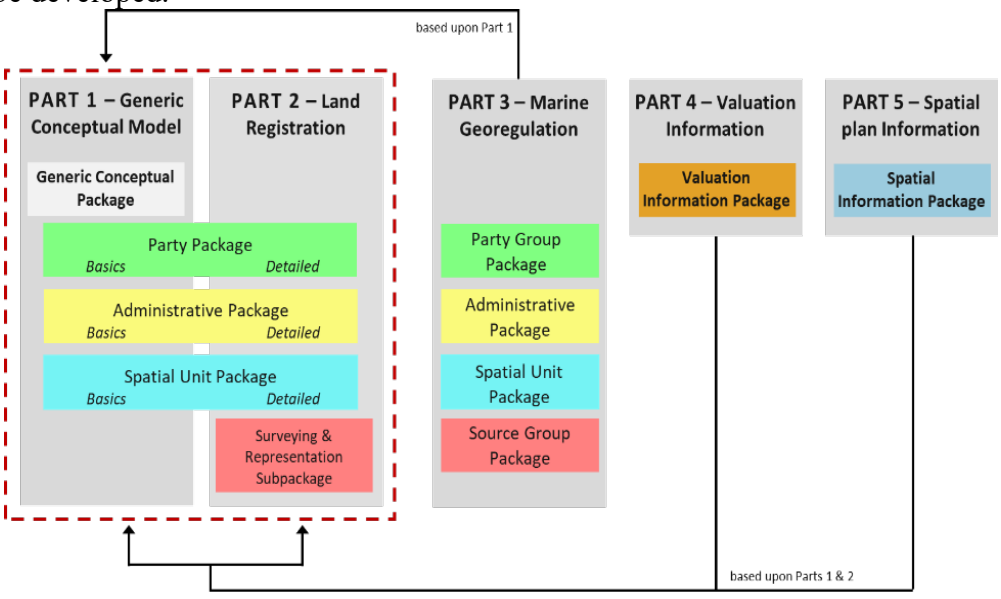


Figure 1 – Investigation of the Parts of the LADM – Edition II which are under development (Kalogianni et al., 2023)

2.1.2 ISO 19152 – Part 4: Valuation Information

ISO19151-4 - Valuation Information has a key objective of establishing a standardized way for communication among stakeholders within and between countries (Kara et al., 2021). It does so by defining a common vocabulary and terminology through its model. However, this standard does not seek to replace existing asset valuation systems; instead, it aims to provide a consistent and shared structure for describing these systems while considering their unique characteristics. Moreover, it strives to offer a scalable foundation for the development and enhancement of efficient real estate valuation systems, adopting the Model Driven Architecture (MDA) approach (Kara et al., 2021).

LADM Part 4 comprehensively represents all stages of immovable property valuation, encompassing ownership recognition, various valuation processes, transaction price recording, statistical sales representation, and handling of appeals. The model's versatility is expected to enable relevant institutions to develop local or national information models and databases while facilitating communication and possible integration of these databases into existing land administration systems (Kara et al., 2021). It is important to note that LADM - Part 4 is specifically tailored to improve administrative valuations of immovable property, such as property taxation, compensation for expropriation, land readjustment, and insurance assessments, but it is also intended for broader evaluative purposes. LADM Part 4 consists of only one package, the Valuation Information Package, which is shown in the next figure.

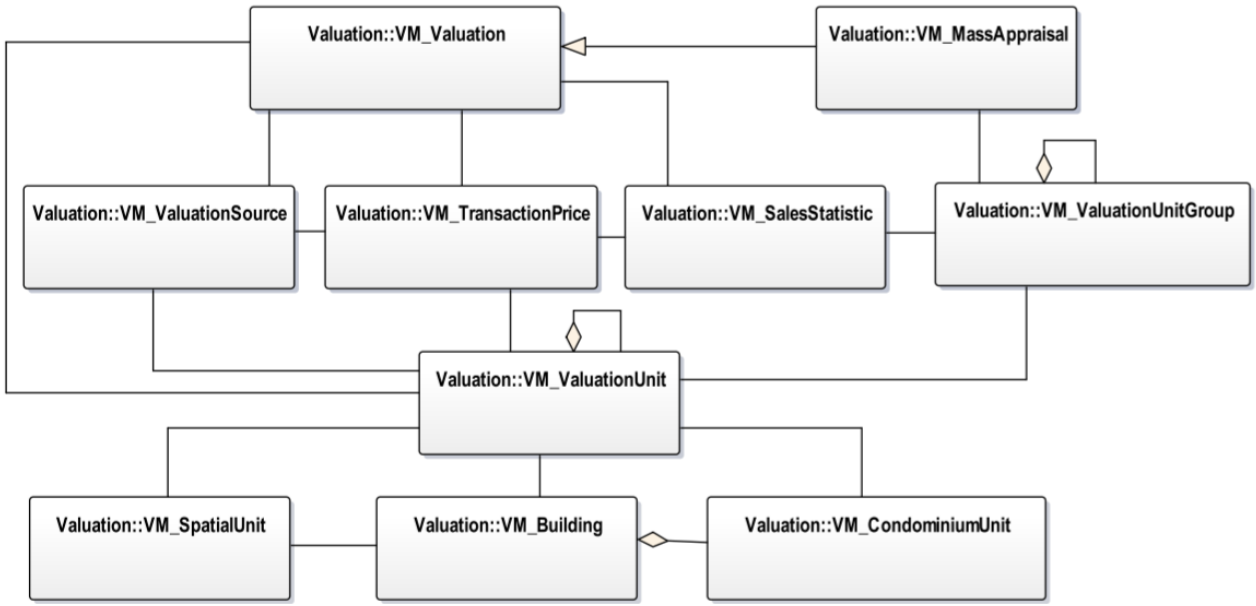


Figure 2 – Main Classes of The Valuation Information Package – Source: (Kara et al., 2023)

2.2 BIM/ IFC for Land Administration Systems and Property Valuation

The primary purpose of the development of BIM models was the modelling of buildings, but due to the complexity of other constructions, such as these of infrastructures, BIM was also adopted by them. The result of this was the increase in applications using BIM and the

parallel increase in the need for richer geometric and semantic information, this led to the increase in the dimensions of BIM (urban dimension) (Hajji et al., 2021). Since establishing the relationships between urban items is its primary priority, managing the urban component is not a simple procedure. Due to its intricate geometry, it may also serve as a physical representation of abstract notions, such as the construction's maximum allowable height, that need to be translated into language that humans can comprehend. As can be shown, many issues with real property rights can be resolved by integrating BIM models into land management systems. Additionally, limits on ownership may be seen due to the discovery of criminal activity.

Atazadeh et al. (2021) mention that the use of BIM/IFC for land administration purposes based on LADM can be achieved through two approaches. The first approach involves extending IFC based on LADM data, while the second approach involves extending LADM itself based on the physical characteristics of IFC. From the research it is concluded that the second approach is not that the optimal, as LADM is a conceptual model that addresses jurisdictional aspects in each country and when attempting to extend it with physical objects would lead to complexity. Additionally, IFC contains hundreds of entities related to building modelling, making it difficult to identify and correlate them with new entities that would serve as extensions of LADM. Therefore, at this study, the first approach, is considered the most suitable for integrating three-dimensional physical and legal information into BIM models.

Moreover, in the work of Su et al. (2021) a novel approach to property valuation is discussed, utilizing data from BIM/IFC models and machine learning methods. It is noted that machine learning methods have advantages over other approaches, as they can take both objective and subjective factors into consideration for valuation. Additionally, they are capable of handling vast volumes of data and providing measures of accuracy and reliability in the outcome. As a result, property valuation can be determined with the most accurate and reliable way. Regarding BIM models, they can store data related to property value, such as material costs, construction timelines, geographical location, energy efficiency, and more. So, utilization of BIM data for the process of the property valuation may be a potential – powerful tool in the future for property valuation.

3 VALUATION INFORMATION MODEL FOR CYPRUS BASED ON ISO19152-4

This Section examines the extent to which the current Cyprus's General Valuation Model can be adapted to the principles, concepts and structure of ISO19152-4, in accordance with the goals of the Valuation Department which belongs to Department of Surveyors (DLS) of Cyprus. To achieve this objective, a mapping is conducted between Cyprus's existing model and ISO19152-4, and the outcomes are then illustrated using UML diagrams. This process leads to the creation of the proposed ISO19152-4: Valuation Information Model for Cyprus.

3.1 Methodological framework

The methodological framework followed for the development of the proposed model of ISO19152 – 4 for Cyprus consists of two main steps. The first step is the analysis of existing

valuation model of Cyprus, and the second one concerns the modelling of the valuation model for Cyprus based on LADM – Part 4.

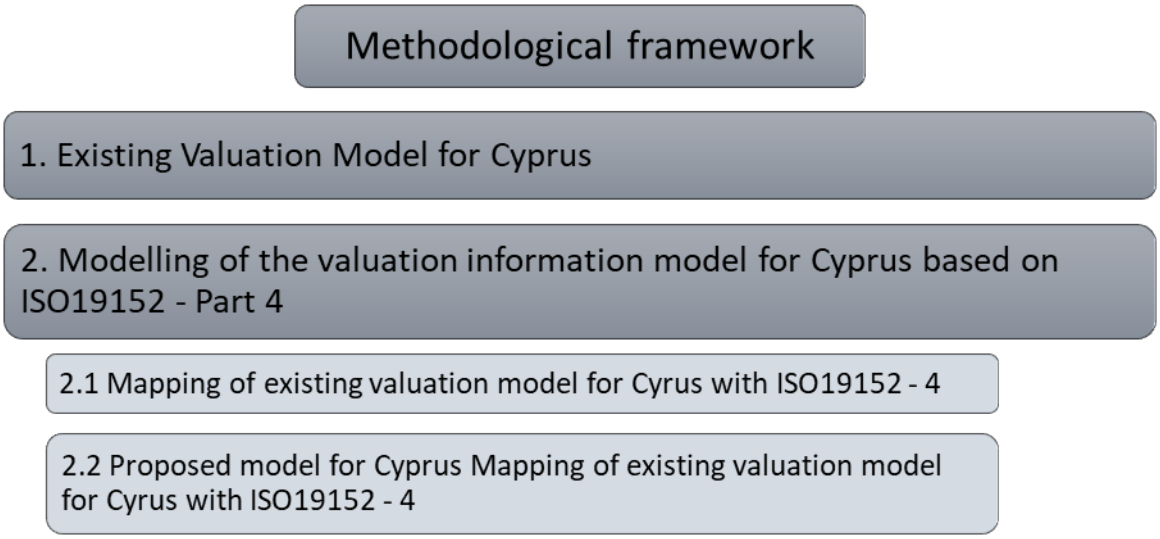


Figure 3 – Methodological framework for the creation of Valuation Model of Cyprus based on ISO19152-Part4

3.2 Current Valuation Model of Cyprus

The responsible organisation for the management and dissemination of the cadastral data in Cyprus is the Department of Land and Surveys (DLS), which consists of twelve departments. The DLS is one of the most important socio-economic pillars of development of Cyprus since the immovable property it is one of the leading factors of progress, prosperity, and development of the country. Its main purpose is the implementation of legislation and procedures for the management of rights, responsibilities and restrictions that connect persons (natural or not natural) with the immovable property. To achieve this, it undertakes the record of the characteristics (geometrical and semantical) of the real property. DLS it

The Department of DLS, responsible for valuation is the General Valuation Department – Valuation's Department. The general valuation in Cyprus, according to the general annual report of DLS (Department of Land and Surveyors, 2021) is conducted every three years, starting from 2018. General valuation/mass appraisal is defined as "*the process of estimating the value of a group of properties on a specific date using common data, standardized methods, and statistical controls*" (Department of Land and Surveyors, 2022). The mass appraisal is implemented through an automated system called the Computer Assisted Mass Appraisal System. Therefore, the value resulting from the general valuation is the general valuation value. As defined by (Department of Land and Surveyors, 2022): *"General Valuation Value" in relation to immovable property means the amount resulting from the conduct of the general valuation or revaluation or revision of the general valuation, which is as close as possible to the value.*

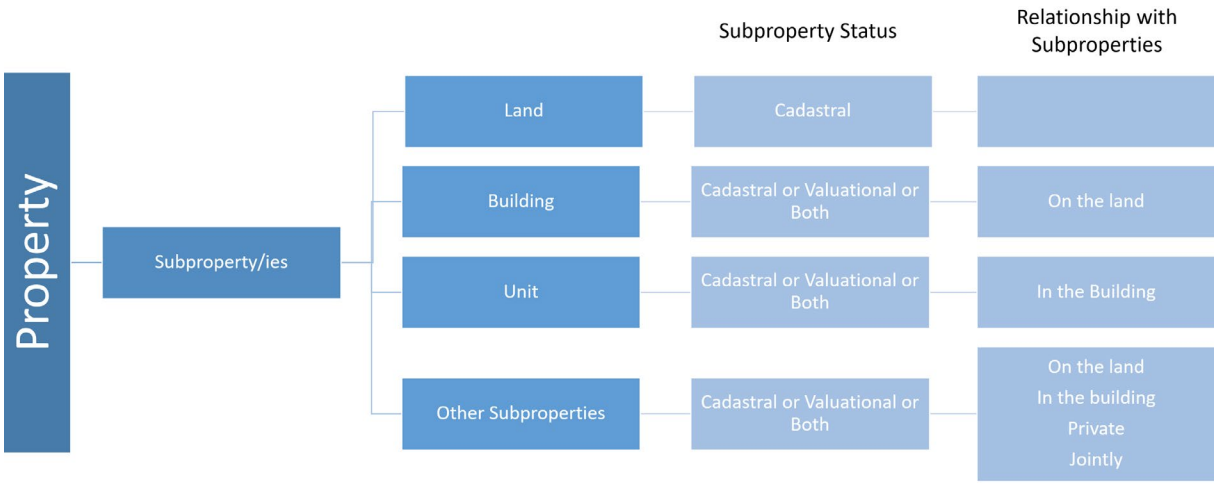


Figure 4 – Types of properties in the existing Valuation Model of Cyprus

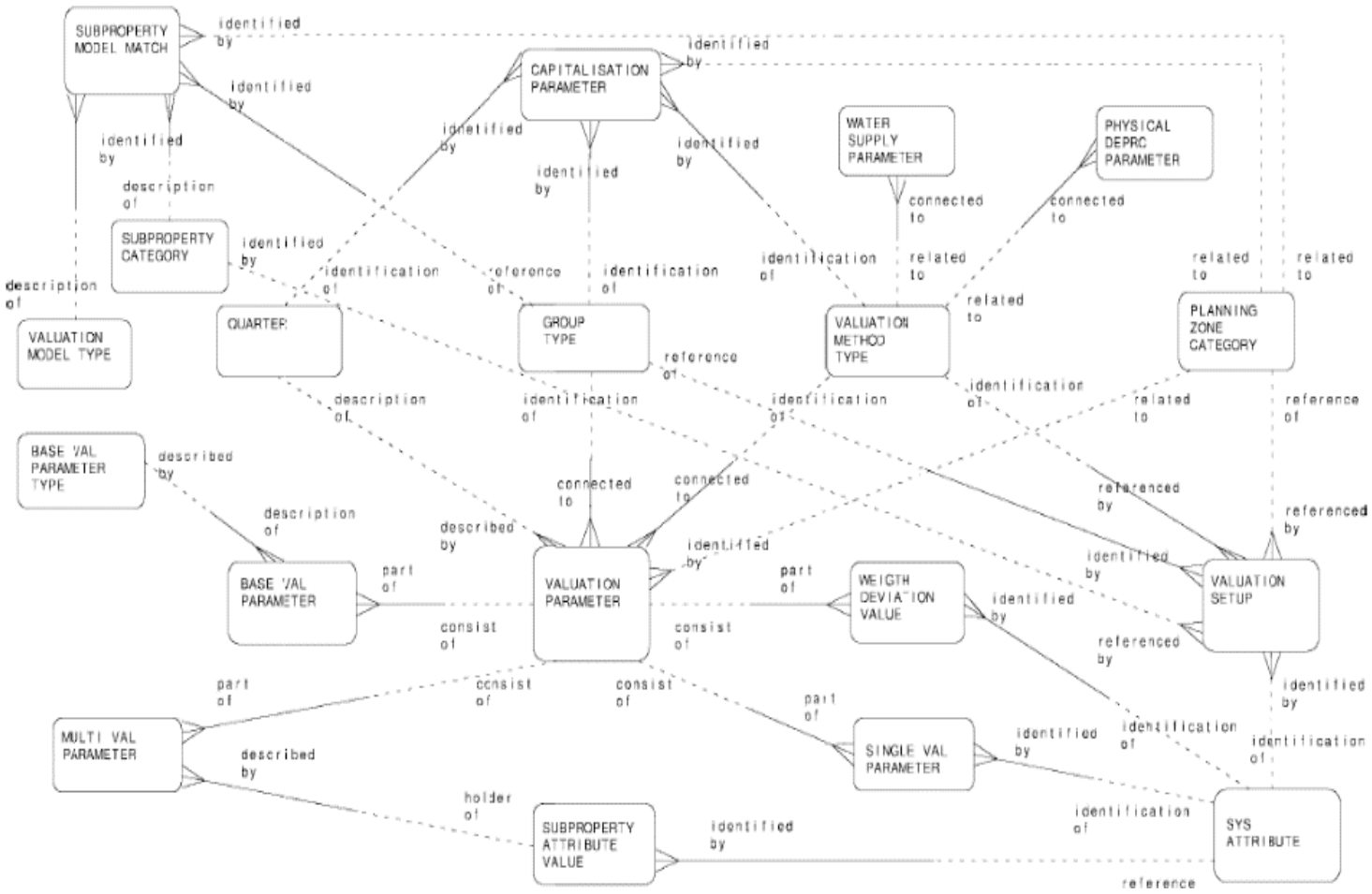


Figure 5 – Existing Valuation Model of Cyprus (DLS)

Figure 5 shows the entity-relationship diagram of the current Valuation Information Model of Cyprus. As it shown, there are plenty entities which consists of the model, denoting the complexity of the model, as well as the high number of parameters related to valuation that shall be considered. The main classes are described in the following paragraphs.

The Subproperty Category within the context of the land registry of Cyprus plays a crucial role in property categorization. These categories encompass various sub-properties, including land parcels, buildings, units within buildings, and other sub-properties like pools and parking spots. Each sub-property type is defined to ensure accurate and comprehensive property assessments. Furthermore, these categories serve as a foundation for valuation models, helping to determine the appropriate valuation approach for each unique subproperty.

The Valuation Model Type class distinguishes between two primary valuation models: Basic Models and Cost Models. These models are integral to the property valuation process, with Basic Models covering land, units, and other sub-properties, while Cost Models specifically apply to units. The choice of valuation model depends on factors like the type of sub-property, the assessment group it belongs to, and the planning zone category. By categorizing properties and selecting the appropriate valuation model, the valuation process becomes more efficient and tailored to the specific characteristics of each property.

Additionally, the Valuation Method Type, Base Val Parameter Type, Base Value Parameter, Valuation Parameter, Valuation Setup, Multi Val Parameter, and Single Val Parameter entities collectively define the methodology, parameters, and procedures used in property valuation. These elements ensure a systematic and comprehensive approach to property appraisal, considering factors such as location, property type, and valuation method. While entities like Sys Attribute, Subproperty Attribute Value, Water Supply Parameter, Quarter, Capitalization Parameter, Physical Depro Parameter (Statistics) and Weigh Deviation Value have become obsolete in the Existing Valuation Model.

3.3 Modelling of the valuation information model for Cyprus based on LADM Part 4

A mapping was made between the entities of the Existing Valuation Model of Cyprus and those of ISO19152-4 Valuation Information both at class and attribute level. At the tables that follow the schema mapping is presented, along with some general comments about the fundamental modelling decisions taken during both the mapping and the development of the proposed model presented in the next subsection:

- The first column of the tables below pertains to the attributes of each respective class in the existing Valuation Model of Cyprus. The first row displays the class name as it exists in the current model.
    - Classes written in **green letters** remain as entities in the proposed model.
- The second column concerns the attributes of each respective class in the under-development ISO19152-4 standard. The first row of this column displays the class name as it exists in the standard and for this reason, all of them start with the prefix "VM."
    - Attributes aligned in the middle already exist in ISO19152-4.
    - Attributes aligned to the left do not exist in the standard, but since they serve the needs of land value estimation in Cyprus, they are added and presented in the proposed model with the same names as they have in the existing Cypriot model.
    - For each attribute, the data type and the code list, where necessary, are provided.
- The third column represents the class in the proposed model for Cyprus to which the attribute in the second column belongs. The first row of this column displays the name

of the class in the proposed model and for this reason, all of them start with the prefix "CY_VM.".

- External classes: The implementation of LADM based on a country's needs can be executed flexibly, adapting to local conditions. Constructing external databases with data such as addresses, land uses, building permit details, etc., falls outside the structure of LADM. However, the possibility of linking LADM with external sources is provided through external entities.
- Code lists: Code lists are used to describe flexible coding and can be expanded by adding new values that are tailored to the country's needs.

3.3.1 Mapping of existing valuation model for Cyprus with ISO19152-4

The schema mapping of the entities of the Existing Valuation Model of Cyprus and ISO 19152-4 is as follows.

Table 1 – Schema Mapping between entities of Existing Valuation Model of Cyprus and ISO 19151-4

Existing Valuation Model of Cyprus	**ISO 19152-4 Valuation Information**
Parcel	**VM_SpatialUnit & VM_ValuationUnit**
SubpropertyCategory	**VM_ValuationUnit**
Unit	**VM_CondominiumUnit & VM_Building**
Building	**VM_Building & VM_SpatialUnit**
OtherSubproperties	**VM_CondominiumUnit**
ValuationModelType	**VM_Valuation**
Group Type	**VM_SpatialUnit & VM_Building**
Planning Zone Category	**New Class (CY_VM_Planning Zone)**
Subproperty Model Match	**VM_Valuation**
Valuation Method Type	**VM_Valuation**
Base Val Parameter Type	**New Class (CY_VM_Planning Zone)**
Base Val Parameter	**New Class (CY_VM_Planning Zone)**
Valuation Parameter	**VM_ValuationUnit**
ValuationSetup	**VM_Valuation**

At the following tables the detailed schema mapping of the attributes of the classes of the Existing Valuation Model of Cyprus and ISO 19152-4 are presented.

Table 2 – Schema Mapping Table of the Parcel class of the existing model with ISO19152-4 respective classes and attribute

Parcel	**CY_VM_SpatialUnit & CY_VM_ExtAddress & CY_VM_ValuationUnit**	
idParcel	vsUID	CY_VM_SpatialUnit
roadRelation	roadRelation(CY_VM_RoadRelation"Code List")	CY_VM_SpatialUnit
typeAccessStreet	roadAccess (CY_VM_RoadAccess "CodeList")	CY_VM_SpatialUnit
relationStreetLevel	relationRoadLevel(CY_VM_RelationRoad Level "CodeList")	CY_VM_SpatialUnit
facade	facade	CY_VM_SpatialUnit

shape	shape	CY_VM_SpatialUnit
view	parcelView (CY_VM_View "CodeList")	CY_VM_SpatialUnit
environment	environment	CY_VM_SpatialUnit
obstacles	obstacles(CY_VM_Obstacles "CodeList")	CY_VM_SpatialUnit
nuisances	nuisances(CY_VM_Nuisances "CodeList")	CY_VM_SpatialUnit
locationValuation	locationValuation	CY_VM_SpatialUnit
slope	slope	CY_VM_SpatialUnit
influencedBeachProtectionZone	influencedAreaFromBeachProtectionZone	CY_VM_SpatialUnit
area	suArea (LA_AreaValue "DataType")	CY_VM_SpatialUnit
sheet	sheet	CY_VM_ValuationUnit
plan	plan	CY_VM_ValuationUnit
plot	plotNumber	CY_VM_ValuationUnit
town	town	CY_VM_ExtAddress
quarter	quarter	CY_VM_ExtAddress
postalCode	postalCode	CY_VM_ExtAddress
registrationCode	registrationCode	CY_VM_ValuationUnit
parcelRegistryValuePrevious	parcelRegistryValuePrevious	CY_VM_ValuationUnit

Table 2 pertains to the mapping of the "Parcel" class from the existing model to the "VM_SpatialUnit" and "VM_ValuationUnit" classes of the standard. As observed from the table, the attribute "idParcel" corresponds to the attribute "vsUID" (aligned in the middle) of the "CY_VM_SpatialUnit" class. Conversely, the attribute "typeParcel" (aligned to the left in the second column) remains as is in ISO19152-4, as there is no corresponding attribute in it. In this specific table, an external class (CY_VM_ExtAddress) is presented with details regarding the Contact Address.

The attributes "sheet" (gender number), "plan" (cadastre plan number), "plotNumber" (Plot Number), "registrationCode" (Land Registry Number), and "parccelRegistryValuePrevious" (previous estimated property value) correspond to the "CY_VM_ValuationUnit" class. It should be noted that the registration code of the parcel (registrationCode) is not the unique parcel number in the cadastre; it is the unique number for each property in this specific registration section (Hajdimina N. 2018)

Table 3 – Schema Mapping table of Building class of the existing model with ISO19152-4 respective classes and attribute

Building	**CY_VM_SpatialUnit & CY_VM_Building & CY_VM_ExtAddress**	
nameOfBuilding	nameOfBuilding	CY_VM_Building
numberOfBuildings numberOfUnits	numberOfBuildings	CY_VM_SpatialUnit
address	address	CY_VM_ExtAddress

Table 3 concerns the mapping of the "Building" class to the "VM_SpatialUnit" and "VM_Building" classes of the standard. In this case, the attributes of one class correspond to attributes of two different classes. Specifically, the attribute "nameOfBuilding" belongs to the "CY_VM_Building" class, and the attribute "numberOfBuildings" belongs to the "CY_VM_SpatialUnit" class.

Table 4 – Schema Mapping table of Unit class of the existing model with ISO19152-4 respective classes and attribute

Unit	**CY_VM_CondominiumlUnit & CY_VM_Building & CY_VM_ExtBuildingPermit**	
Building Permit Number	buildPermitID	CY_VM_ExtBuildingPermit
Date of Issuance of Building Permit	permitIssuanceDate	CY_VM_ExtBuildingPermit
Construction Permit Number	constructionPermitID	CY_VM_ExtBuildingPermit
Date, Construction Permit Number	constructionPermitIssuanceDate	CY_VM_ExtBuildingPermit
File Number of Construction Permit	constructionPermitFolderID	CY_VM_ExtBuildingPermit
Final Approval Certificate Number	finalApprosvalCertificateID	CY_VM_ExtBuildingPermit
Date of Issuance of Final Approval Certificate	finalApprovalCertificateIssuanceDate	CY_VM_ExtBuildingPermit
buildingID	buID	CY_VM_Building
RealUse	buCurrentUseType	CY_VM_Building
	cuCurrentUseType	CY_VM_Condominium Unit
groupType	useType: VM_Building/CondominiumUseType "CodeList"	CY_VM_Building
	useType: VM_Building/CondominiumUseType "CodeList"	CY_VM_Condominium Unit
typeStructure	constructionMaterial: VM_ConstructionMaterialType "CodeList"	CY_VM_Building
ageStructure	dateOfConstruction:	CY_VM_Building
ageRenovation	dateOfRenovation:	CY_VM_Building
typeRenovation	typeRenovation	CY_VM_Building
floorNumber	numberOfFloor	CY_VM_Building (Number of floors in the building)
floorNumber	floorNumber	CY_VM_Condominium Unit (The floor number

		of the condominium unit)
numberGate	cuNumber	CY_VM_Condominium Unit
-	cuID	CY_VM_Condominium Unit (The identifier of the condominium unit)
orientation	buOrientation:CY_VM_Orientation	CY_VM_Building
orientation	cuOrientation:CY_VM_Orientation	CY_VM_Condominium Unit
view	cuView: CY_VM_ViewType "CodeList"	CY_VM_Condominium Unit
categoryLuxury	categoryLuxury	CY_VM_Building
statusStructure	constructionQuality:CY_VM_ConstructionQuality "CodeList"	CY_VM_Building
issuesUnit	constructionIssues	CY_VM_Building
closedArea	area = CY_VM_AreaValue "DataType"	CY_VM_Building
closedArea/ parkingArea/ poolArea/ basementArea/ auxiliarySpace/ externalBuildings	condominiumArea: CY_VM_AreaValue "DataType"	CY_VM_Condominium Unit
openedBalconyArea	openedBalconyArea	CY_VM_Condominium Unit
closedBalconyArea	closedBalconyArea	CY_VM_Building & CY_VM_Condominium Unit
numberParikingSpots	numberParikingSpots	CY_VM_Building
if useType= 62 or 63, then complete the dimensionsShopsUnit, heightShop, relationShopsWithStreet		
dimensionsShopsUnit	dimensionsShopsUnit	CY_VM_Building & CY_VM_Condominium Unit
heightShop	heightShop	CY_VM_Building & CY_VM_Condominium Unit
relationShopsWithStreet	relationShopsWithStreet	CY_VM_Building & CY_VM_Condominium Unit

Table 4 deals with the attributes of the "Unit" class in the existing Cyprus model, which correspond to two different classes in ISO19152-4, specifically "VM_Building" and "VM_CondominiumUnit." Due to the presence of several attributes in the "Unit" class related to building permit details captured in the current Cyprus model, an external class was created for the proposed model to store and connect them to an existing external database. This external class is named "CY_VM_ExtBuildingPermit." Regarding the

"VM_CondominiumUnit" class, it pertains to co-dominant units such as apartments, pools, parking spaces, etc. For optimal modeling, attributes such as "closedArea,"parkingArea," "poolArea," "basementArea," "auxiliarySpace", and "externalBuildings" present in the existing Cyprus model are captured under a single attribute "area," as their differentiation is handled through another attribute. One particularity in this case is the constraint related to recording the attributes "dimensionsShopsUnit," "heightShop," and "relationShopsWithStreet," where their recording must be applicable only if the unit's use is categorized as a shop or industry.

3.3.2 Proposed ISO19152-4: Valuation Information Model for Cyprus

Based on the mapping of entities and attributes from the existing General Valuation Model of Cyprus to the corresponding elements of the ISO19152-4 Valuation Information standard, the proposed valuation model for Cyprus has been developed, customized to meet the needs of Cyprus. The goal is to create a flexible model that retains the essential characteristics of the existing Valuation Model of Cyprus while incorporating necessary additions to fully serve the country's requirements.

During the modelling process, where necessary, additional attributes are introduced that are not described in the ISO19152-4 model but are deemed essential to fulfilling the country's needs. It's noted that the nomenclature is retained for reused ISO19152-4 entities and attributes, while newly added components are named in English. Throughout the final model, all classes, data types, and code lists are prefixed with "CY_VM." Below, a detailed presentation of the classes, their attributes, and code list values of the proposed model is presented, while at the end of the Section, the proposed model is presented.

Figure 3 presents the class "CY_VM_SpatialUnit" along with its attributes. This class pertains to the parcel accompanied by attributes derived from the form (DLS, 2021). The parcel serves as the subject of the valuation unit. Code lists refer to predefined values of specific attributes based on the specifications of the existing Valuation Model of Cyprus. For example, the code list of "CY_VM_ViewType" adopts values like limited, regular, privileged, sea, and panoramic. This is because in the existing Valuation Model of the attribute "view" takes default values such as limited, regular, privileged, sea, and panoramic view (DLS., 2021).

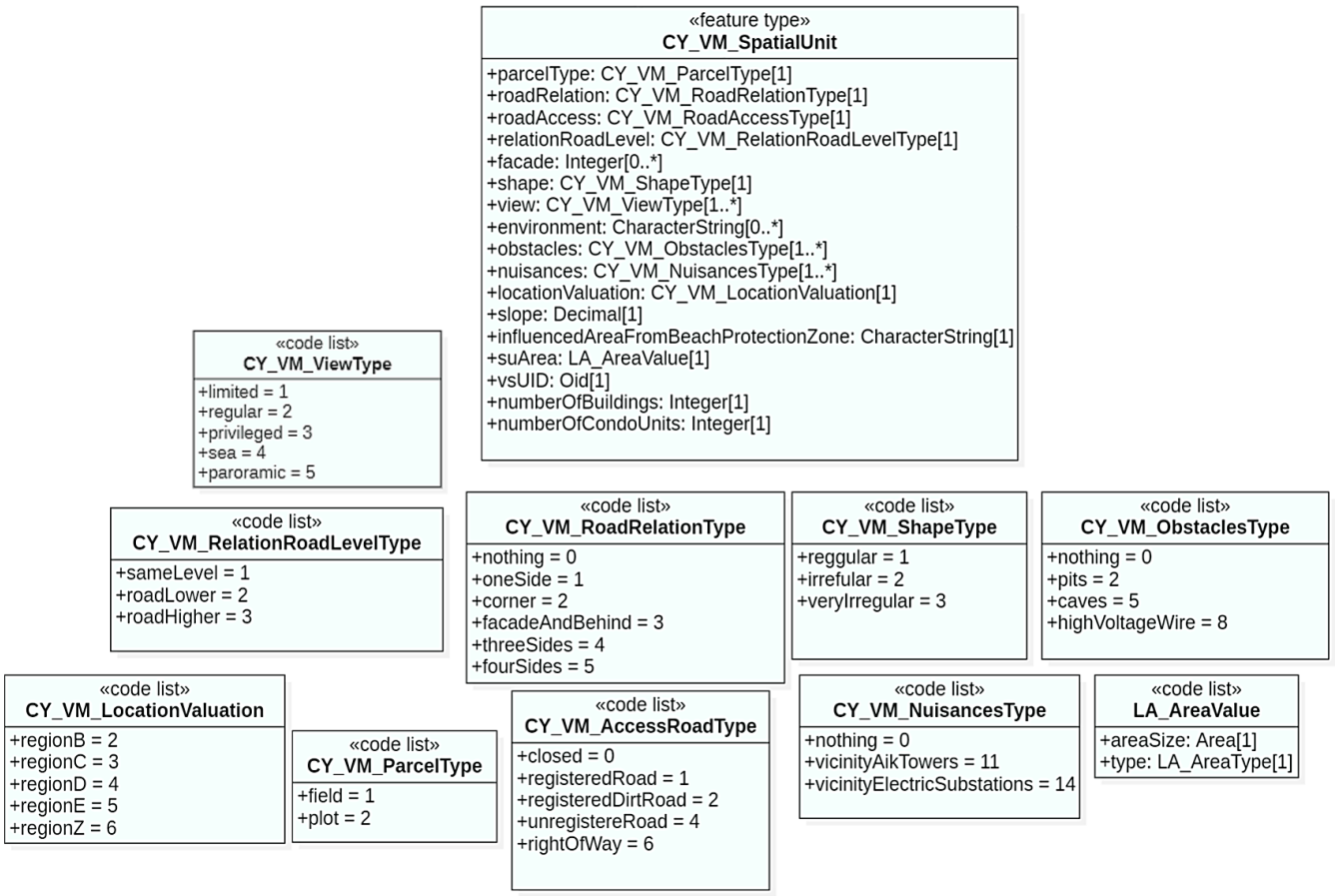


Figure 6 – Proposed class CY_VM_SpatialUnit with its code lists

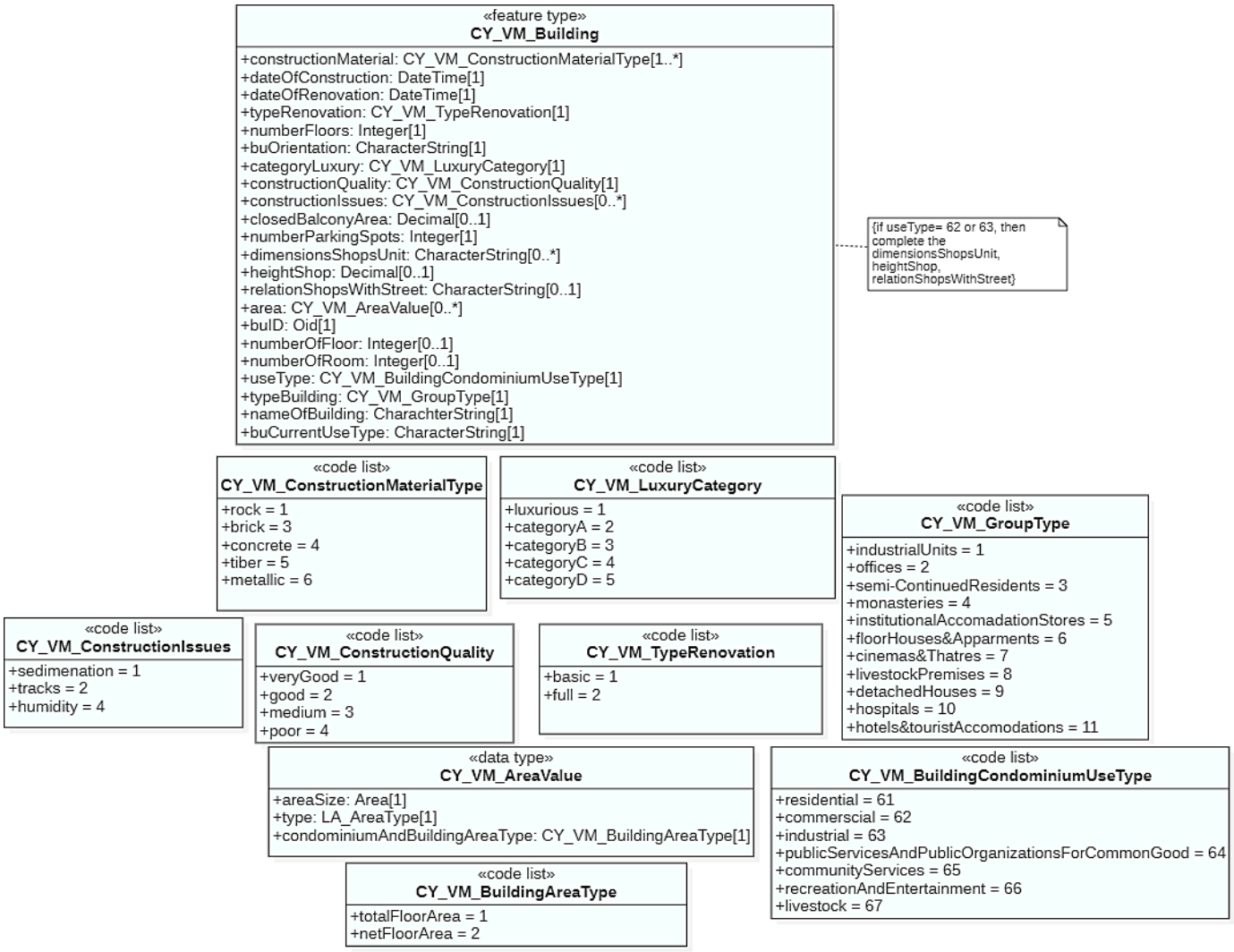


Figure 7 - Proposed class CY_VM_Building with its code lists and data type

Figure 7 illustrates the class "CY_VM_Building with attributes", some of which are taken into consideration during the valuation process. This class encompasses various types of buildings, including condominiums. In this case, a constraint is introduced in the form of a comment, which is derived from the General Valuation Methodology (Department of Land and Surveyors 2022). This constraint pertains to recording the dimensions of the shop, its height, and its relationship to the road in cases where the building's usage type is either commercial or industrial. Value lists created align with the General Valuation Methodology and the form (Department of Land and Syrveors 2021).

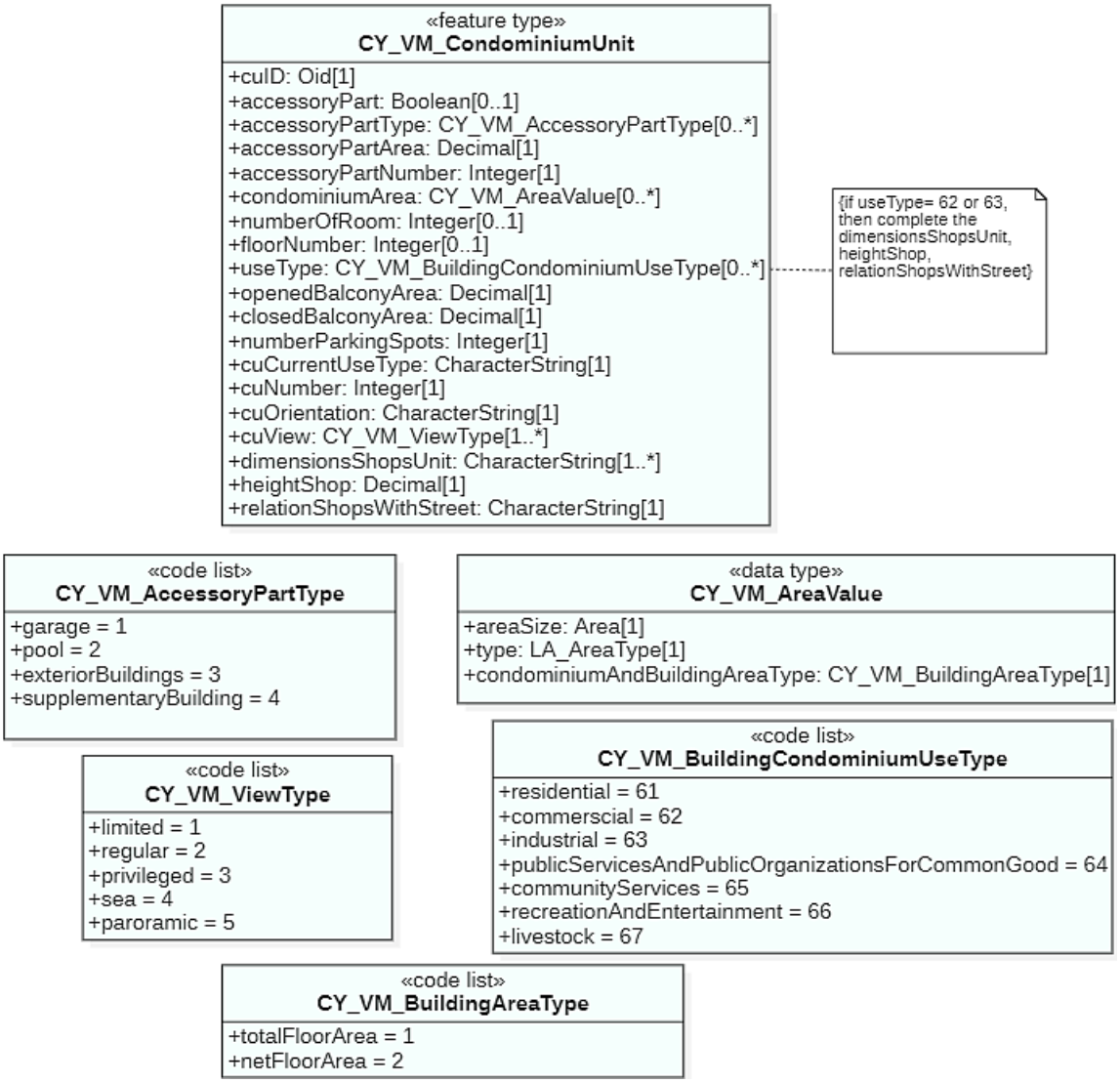


Figure 8 - Proposed class CY_VM_CondominiumUnit with its code lists and data type

Figure 8 corresponds to the class "CY_VM_CondominiumUnit", where, according to the ISO19152-4 standard, even storage spaces, pools, external buildings, and auxiliary areas are recorded. Certain attributes of "CY_VM_CondominiumUnit" are repeated in the "CY_VM_Building" class, as is the case in the standard. One key difference is that this class includes the attribute "view," unlike "CY_VM_Building". This distinction arises because in cases where the building is a single-family home, the view is recorded as an attribute in the "CY_VM_SpatialUnit" class. As for the attribute-class (data type) "condominiumArea," it captures the type and size of the area to be estimated.

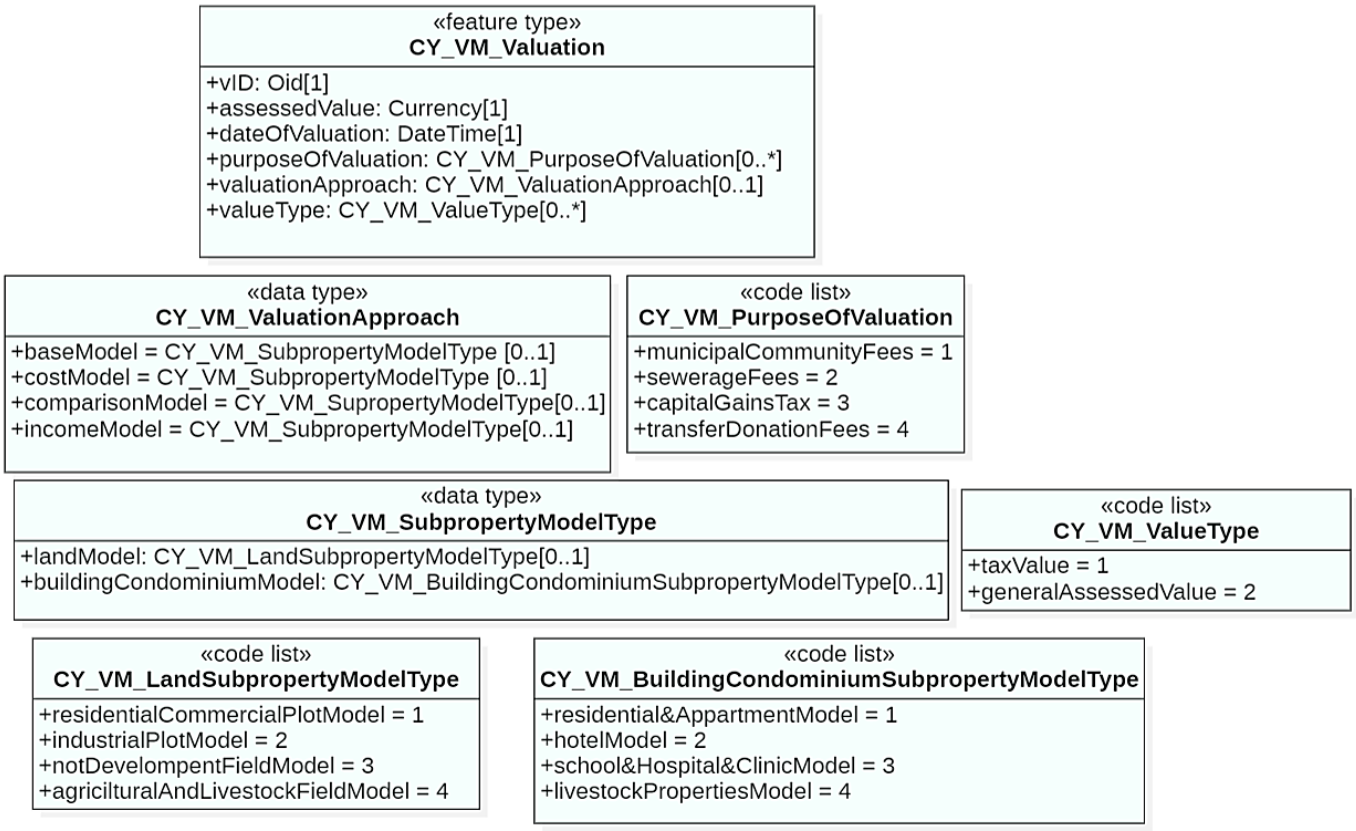


Figure 9 - Proposed class CY_VM_Valuationt with its code lists and data type

Figure 9 illustrates the class "CY_VM_Valuation", which pertains to the class involved in the valuation process. The attribute-class (data type) "CY_VM_ValuationApproach" represents all the valuation models referenced in the analysis of the current state of Cyprus's valuation model. This specific attribute-class consists of individual attribute-classes, taking the value "CY_VM_SubpropertyModelType". This data type value encompasses the subproperty valuation models. It would be beneficial to provide a specific example of how the appropriate valuation model is selected for a particular valuation unit. For instance, if the unit to be valued is a residential building, then the "valuationApproach" value might be the "baseModel" or the "costModel" (depending on the chosen system method). Following that, the "buildingCondominiumModel" with a value of 1 (residential & apartment model) would be selected.

Moreover, Figure 10 presents the class "CY_VM_ValuationUnit", which pertains to the class of the valuation unit. As shown, the valuation units comprise land, building, and condominium units. The attribute "sbpiID" is visible here, referred to as the unique property identification number (for either a unit or a parcel) (Hajdimina N. 2018)

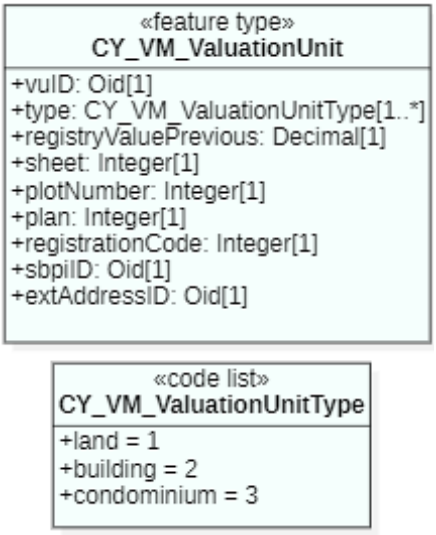


Figure 10 - Proposed class CY_VM_ValuationUnit with its code list

Figure 11 presents the class "CY_VM_PlanningZone" along with its code list. This class pertains to urban planning regulations. The unique code list presented here pertains to the value per square meter when the valuation unit is a parcel, and the cost value when the valuation unit is a building or a condominium unit. The values that these two codes can take are determined based on the category of the planning zone.

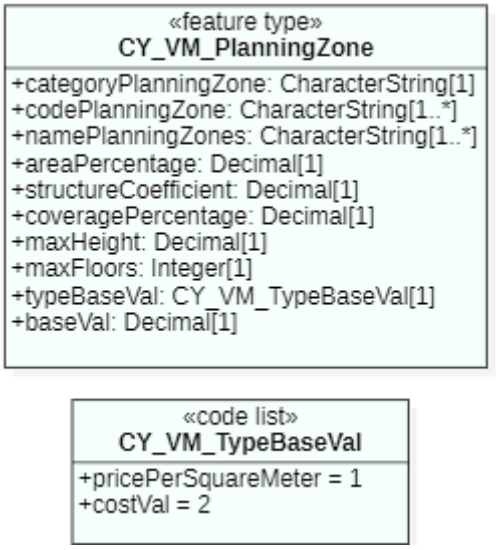


Figure 11 - Proposed class CY_VM_PlanningZone with its code list

The classes "CY_VM_ValuationUnitGroup" and "CY_VM_MassAppraisal" were not present in the existing model of general valuation in Cyprus but were added to the proposed model to ensure completeness and compatibility with theISO19152-4. It is noted that their characteristics are the same as those defined in the standard.

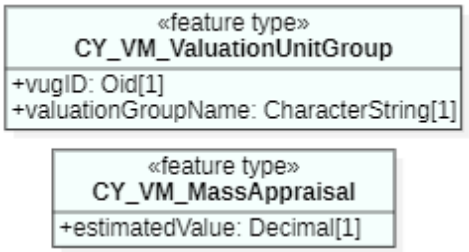


Figure 12 - Proposed classes CY_VM_ValuationUnitGroup and CY_VM_MassAppraisal

The external class "CY_VM_ExtAddress" is implemented in the proposed model, since some of its characteristics are appeared in Table 2 and Table 3 of the existing model of Cyprus.

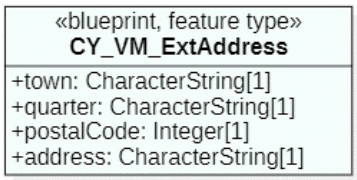


Figure 13 - Proposed class CY_VM_ExtAddress

The external class " CY_VM_ExtBuildingPermit " is introduced in the proposed model due to the presence of certain characteristics within it that appear in the Building table *Table 3* of the existing Cyprus model. As previously mentioned, it is believed that this class can be linked to an existing database of building permits.

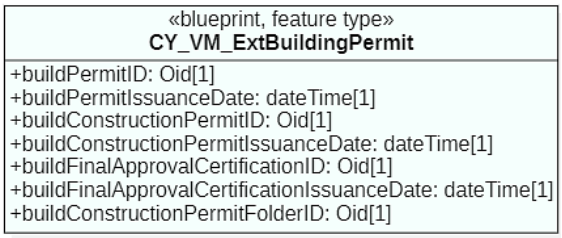


Figure 14 - - Proposed class CY_VV_ExtBuildingPermit

Figure 15 presents the proposed valuation model for Cyprus based on the ISO19152-4 standard. The relationships between classes are predefined by the ISO19152-4 standard. It would be beneficial to explain the relationships between classes using some examples. One specific relationship is between the Building class (CY_VM_Building) and the Condominium Unit class (CY_VM_CondominiumUnit), referred to as "composition." In this relationship, Condominium Units can inherit information from Buildings, and if a Building class is deleted, the associated Condominium Units will also be deleted. Another notable relationship is the one between Valuation (CY_VM_Valuation) and Mass Appraisal (CY_VM_MassAppraisal), named "inheritance." In this case, Mass Appraisal entities inherit characteristics from Valuation entities. This is referred to as a "parent-child" relationship.

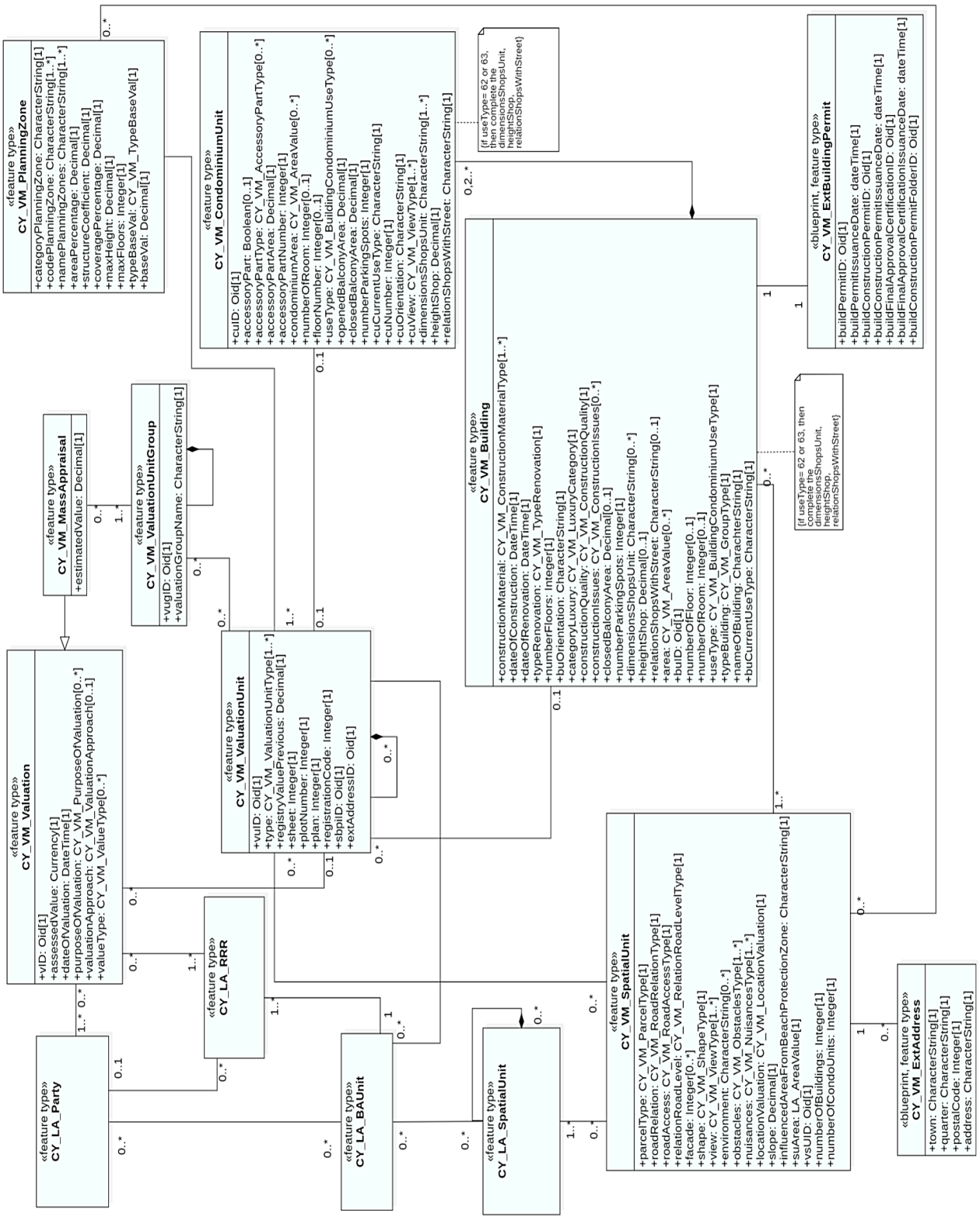


Figure 15 - The proposed Valuation Model of Cyprus based on ISO19152-4

Other relationships between classes are referred to as associations. An example of such a relationship is between Valuation Unit (CY_VM_ValuationUnit) and Valuation (CY_VM_Valuation). This relationship is translated as "a Valuation Unit can be associated with 0 to many [0..*] instances of Valuation processes, while conversely, a Valuation can be associated with 0 to 1 [0..1] Valuation Unit." Additionally, a Valuation Unit can be associated with 0 to many [0..*] transaction cases (meaning a Valuation Unit can be subject to property transactions). Furthermore, multiple Valuation Units (CY_VM_ValuationUnit) are related to 0 to many [0..*] instances of Valuation Unit Groups (CY_VM_ValuationUnitGroup) in a subdivision and in a real estate market zone.

4 CASE STUDY: APPLYING THE PROPOSED MODEL FOR A HOUSE IN CYPRUS

This Section presents the technical application exploring the utilization of data from BIM models for their reuse in land management issues, specifically the valuation of properties, within the framework of ISO19152 - 4 for the case of Cyprus. For this case, a mixed-use house has been modelled from 2D Drawings, in Revit and exported in IFC format.

4.1 Integration of valuation information in the IFC based on the proposed Valuation Model of Cyprus

The integration of valuation information based on LADM into the IFC is accomplished by storing the relevant information within the entities of IFC. The entities capable of adopting such information are IfcSpaces, IfcZones, and IfcSite (Oguzhan Mete et al., 2022). By incorporating the appropriate attributes into these entities, it becomes possible to automatically provide information for general valuation purposes from the IFC model. Furthermore, during the effort to integrate valuation information into the aforementioned entities, it was discovered that the IfcBuilding and ProjectInformation entities can also adopt relevant information for the buildings. The characteristics of the entities of the proposed Valuation Model of Cyprus, will be stored as follows in the IFC entities:

Characteristics which IfcZone will adopt are:

- CY_VM_CondominiumUnit
- CY_VM_ValuationUnit

Characteristics which IfcSite will adopt are:

- CY_VM_SpatialUnit
- CY_VM_ValuationUnit

Characteristics which IfcSite or Project Information will adopt are:

- CY_VM_Building

Table 5 – Mapping the entities of Revit & IFC – Integration characteristics CY_VM

Entity in Revit	Entity in Ifc	Attribute
HVAC Zones (Analyze Tab) or ZoneName (Shared Parameters)	IfcZone	• CY_VM_CondominiumUnit • CY_VM_ValuationUnit
Space	IfcSpace	• CY_VM_CondominiumUnit
Toposurface (Massing & Site)	IfcSite	• CY_VM _SpatialUnit • CY_VM_ValuationUnit
Project Information	IfcBuilding ή Project Information	• CY_VM_Building

4.2 Visualization of the CY_VM characteristics in the IFC entities

This section refers to the visualization of the characteristics of the entities of the Proposed model of Cyprus.

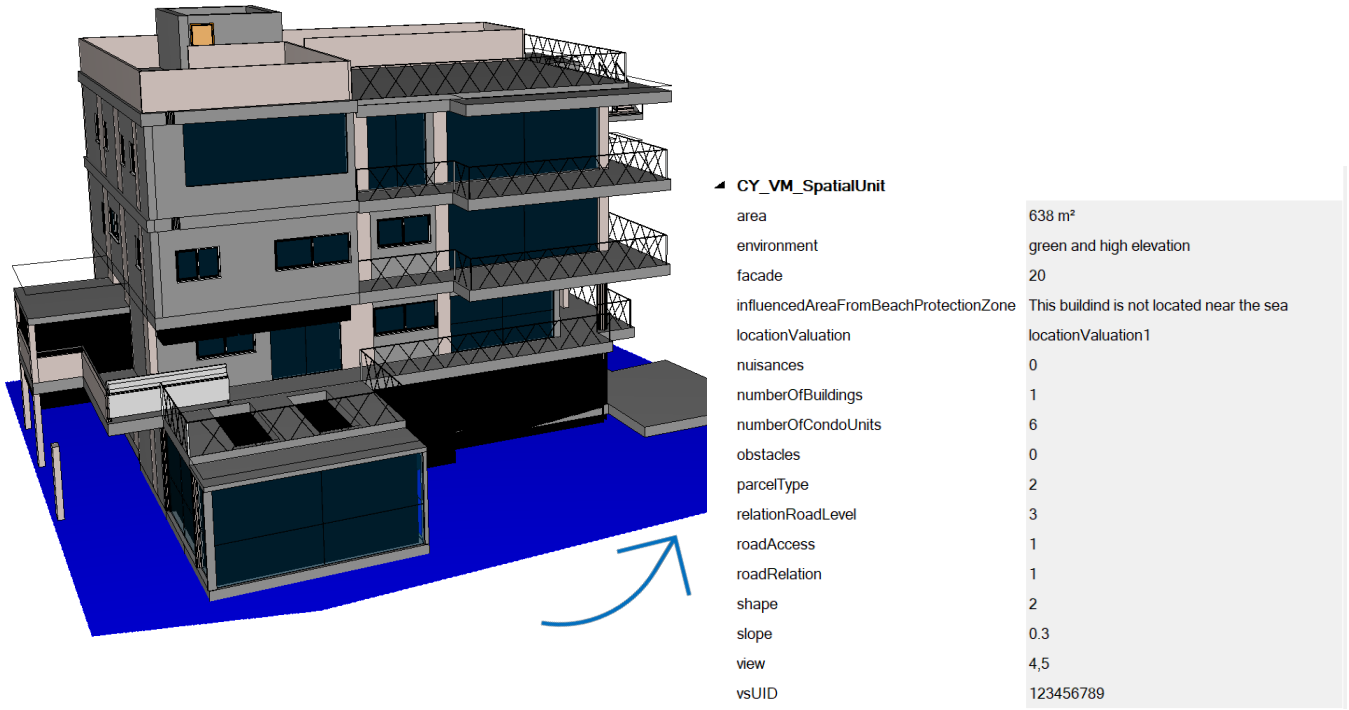


Figure 16 – Visualization of the characteristics of the CY_VM_SpatialUnit in IFC format – DDScad viewer

Figure 16 shows the characteristics of the class CY_VM_SpatialUnit. Highlighted in blue is the IfcSite entity. Also, characteristic's value is based on the CY_VM_SpatialUnit code lists Figure 6 as mentioned above.

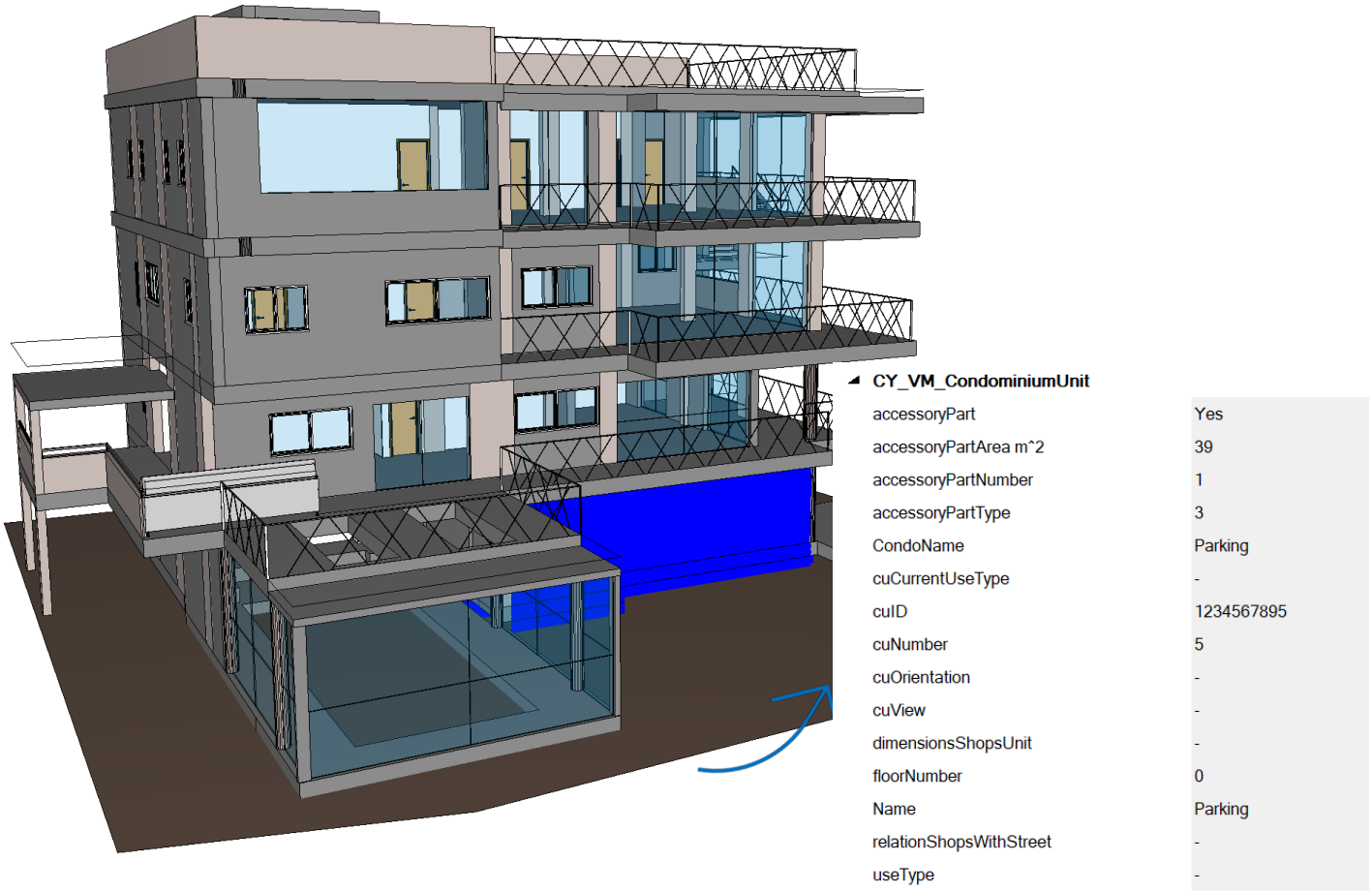


Figure 17 – Visualization of the characteristics of the CY_VM_CondominiumUnit in IFC format – DDScad viewer

Figure 17 depicts the attributes of the class CY_VM_CondominiumUnit. These attributes were stored in the Revit Space entity using Schedules. The reason they were stored in the Space entity in this specific case (Name=Parking) was that this condominium unit consists of a single space. The entity IfcSpace is highlighted in blue underline color.

5 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The results, as demonstrated by both the findings and the proposed model, underscore the under-development standard's capability to meet the requirements of an existing general valuation model tailored to the data specific to the studied country. This application also highlights the flexible semantic structure of the standard, showcasing its adaptability to the unique of individual countries or regions. Consequently, it offers a pathway for countries to

align their land management system and land value estimation methodologies with this standard, while considering the relevant legislation and regulatory frameworks.

In Section 3, certain challenges were encountered during the modelling process. Initially, the mapping of entities between the existing valuation model of Cyprus and ISO 19152-Part4 was not a one-to-one (1→1) correspondence, necessitating appropriate adjustments. Additionally, several attributes present in the existing valuation model of Cyprus were absent in ISO 19152-4, requiring them to be modelled using the specific "language" followed by ISO 19152-4. However, due to the flexible semantic structure of ISO 19152-4, all the difficulties were mitigated. The model allows to model new entities that were deemed necessary for the optimal representation of the valuation model, thus covering all its needs. This flexibility was particularly evident during the modelling of code lists. Moving on to the technical application presented in Section 4, the modelling of an existing building in BIM/IFC format was carried out, followed by the incorporation of valuation attributes into the BIM model. This integration enables the automatic retrieval of this information for valuation purposes, streamlining the process.

5.2 Recommendations for future work

In the context of creating the valuation model for Cyprus according to ISO 19152-Part 4, this paper operates at the conceptual level, without implementation of the database itself. Therefore, the next step involves establishing a database for the proposed conceptual valuation model in aligning with ISO 19152-Part 4 for Cyprus and enriching it with real-world data that can be sourced from the General Valuation Department - Valuation Division, in collaboration with relevant departments. The expected outcome of this effort is the facilitation of bidirectional data exchange, allowing the IFC model to both receive and contribute data to the database. The next stage of the technical application may involve the three-dimensional visualization of the model. This entails the collection of spatial and semantic data from the General Valuation Department - Valuation Division and other relevant authorities. Utilizing this date three-dimensional buildings' representations (at Level of Detail 2 - LoD2) for adjacent properties can be generated for a specific area, alongside the integrated BIM model. In this context, by integrating land value information for adjacent properties, queries regarding land values can be supported, with results presented visually.

Implementing such an application within a three-dimensional environment serves to comprehensively represent all the characteristics considered in land value estimation. Specifically, by modelling elements of the surrounding environment, such as utility poles, etc., which can be optimally incorporated into the valuation model (like obstacles). The same applies to features such as views, proximity to the sea, and so on. As of the current status, ISO 19152-Part 4 has not yet received official ratification as an ISO standard by the global standardization organization ISO, as the first edition of the ISO 19152:2012 LADM standard is presently undergoing a revision process. Consequently, since minor modifications to the standard can emerge through the standardization process, the proposed model will be adjusted accordingly if necessary. Within this context, upon its adoption as an international standard, a validation process will be initiated to evaluate the compliance level of the proposed model, as established through the conceptual mapping and according to the compliance matrix included in the standard.

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Mass Property Valuation in Serbia

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Key words: property valuation, mass appraisal, LADM Valuation Information Model

SUMMARY

Mass property valuation is the process of determining market value of the immovable property on a certain date, which is done for each registered property in the Real Estate Cadastre using registered real estate data, with application of standardized methods and statistical testing. Mass valuation of real properties was introduced into the legislation of the Republic of Serbia in 2009 within the Law on State Survey and Cadastre. The law prescribes keeping of records of real property market prices by the cadastral authority for the purposes of mass valuation. Numerous methods of mass valuation have been developed, among which the most used is multi-parameter regression analysis (MRA). Multi-parameter regression provides the ability to analyze the relationship and impact on the price of multiple market factors such as area, location, number of floors, rooms, quality of construction, etc. According to the law, establishment of a system of mass real property valuation should be carried out in several phases including a formation of a model for mass valuation, legal adjustments, collection of data from a variety of sources, etc. For this purpose, cadastral authority implemented the Real Estate Price Register, which is the first step towards the mass valuation, and it assures collection of data from the real estate market. Other steps are yet to be completed, to establish mass valuation in Serbia.

Based on the developed Serbian LADM profile and LADM Valuation Information Model, a data model for the property valuation in Serbia was developed in our previous work. It defined the class RS_VM_MassAppraisal intended for future use when the process of implementation of mass valuation in Serbia is completed. In this paper, we further elaborate this model, develop a case study for the mass evaluation based on MRA for the city of Novi Sad, and compare it to the individual valuation explored in the previous work. The biggest challenge is a selection of parameters that affect the value of a property, i.e., elimination of those characteristics that do not influence the value. At the end, we conclude by analyzing the possible use of other automated valuation models, which are AI based models concerning real estate market analyses and valuation, among which MRA is the oldest and most common one, but may experience certain weaknesses, which can lead to lowered effectiveness of the valuation.

1. INTRODUCTION

Assessment of the market value of real property is a prediction of its market value based on established standards, collected data on real property, its location, legal status, market situation, characteristics and quality, etc. It is a complex process that involves many factors that directly or indirectly affect the value of real property. The need for valuation arises in taxing, real estate transactions, mortgage loans, making investment decisions, etc. Real property valuation is performed by individual and mass valuation procedures. Individual valuation of real property means determining the value of individual real property on a certain date. Mass valuation of real property is defined as the systematic valuation of a group of real properties on a given date, using standardized procedures and methods of mathematical statistics. Mass valuation, as opposed to individual real property valuation, requires the development of a valuation model that can incorporate the impacts of supply and demand in large areas.

Mass property valuation is the process of determining market value of the immovable property on a certain date, which is done for each registered property in the Real Estate Cadastre using registered real estate data, with application of standardized methods and statistical testing. The mass assessment of immovable property values is done through the development of models for property valuation, which is determined according to the specifics of each individual real estate submarket (land, apartments, business space, etc.) on the territory of the Republic of Serbia. Mass assessment of property values ensures uniformity and consistency in valuation based on market principles. Mass immovable property valuation must be in accordance with valid international standards and best practice guidelines (International Association of Appraisal Officers – IAAO (IAAO, 2017); Royal Institution of Chartered Surveyors – RICS; TEGoVA European Valuation Standards (TEGoVA, 2012)).

The main role of the mass property valuation system is the calculation of property taxes, as well as to support transparent and open property market. The mass property valuation system is used by a large number of developed countries, which is why there is significant international practice, guidelines and instructions (Baranska, 2013; Smodiš and Mitrović, 2012; Tomić et al., 2021). The results that arise from such system are transparency and openness of the market, better economy of the system, neutrality, compliance with social and economic policy, improved administration, etc. (Branković and Tesla, 2011). The mass property valuation system is always a multi-purpose system, which ensures the objectivity of the price, equal and fair treatment to all citizens, a realistic assessment free from temporary market influences.

Following the example of other countries (e.g., Slovenia, Sweden, etc.), mass valuation of real properties was introduced into the legislation of the Republic of Serbia in 2009 within the Law on State Survey and Cadastre (2009). In 2011, in accordance with this law, the Republic Geodetic Authority included in its jurisdiction the evaluation and management of immovable property values. The Law defines that the property valuation means determining the market value of a property whose value is determined by procedures and methods of mass property valuation. This law also defines the keeping of records of real property market prices by the cadastral authority for the purposes of mass valuation. The Rulebook on Real Estate

Valuation was published in 2014 and regulates the procedure, method and methodology for real estate valuation using the procedures and methods of mass property valuation. According to the law, establishment of a system of mass real property valuation should be carried out in several phases: preparation and adjustment of legal regulations; establishment and improvement of the real estate price register; verification and analysis of data from the real estate market; formation of a model for mass valuation; assessment and recording value data for the entire real estate fund. To carry out all the steps, cadastral authority implemented Real Estate Price Register (2021). This register is the first step towards the mass valuation, and it assures collection of data from the real estate market. Other steps have yet to be implemented. Numerous methods of mass valuation have been developed, but the method that has stood out for its simplicity, applicability, efficiency, and is the most commonly used, is multi-parameter regression analysis (Benjamin et al., 2004). Multi-parameter regression provides the ability to analyze the relationship and impact of multiple market factors such as area, location, number of floors, rooms, quality of construction and other characteristics. The biggest challenge is a selection of parameters that affect the value of a property, i.e. elimination of those characteristics that do not have an effect on the value (Božić and Milićević, 2012).

The key to the success of such system is collection of accurate, complete and up-to-date data, as well as development of appropriate valuation models for each property value submarket (e.g. urban/agricultural land, houses, apartments in different value zones, etc.). Accurate and up-to-date real property data is needed to appropriately assess the values of real properties. A key element for real property valuation are public registers, which enable regular maintenance and updating of data, as well as links between these registers, which have the necessary information for valuation. The Real Estate Cadastre provides data needed to assess the value of real properties, but they are not sufficient for today's complex valuation practice. By recording the information produced through valuation activities and recording market indicators, further market analysis can be enabled, and a more reliable assessment of the value of real properties can be made.

Some of the basic postulates for the mass valuation that provide an objective value that can realistically represent the open real estate market include formation of accurate and complete datasets, namely all immovable properties must be registered and all prices verified. To achieve this, data collection and harmonization can be established using software architecture that is service oriented (service-oriented architecture, SOA). Data sharing is facilitated by the means of Web services. This can be done by implementing a service-oriented architecture on top of the real estate cadastre data and which will enable access to real-time data. Therefore, linked registers and well-organized and complete datasets are prerequisite for the development of successful property valuation models.

To present all relevant aspects of mass property valuation in Serbia, the paper is structured as follows. After the introduction, the mass property valuation system and its core components are presented in Section 2. Section 3 presents LADM based conceptual model for mass property valuation. The process of mass property valuation that includes data collection, data processing and model development is presented in the Section 4. The development of the mass property valuation model is presented in Section 5, following the case study in the Section 6. Discussion and conclusions are given afterwards.

2. MASS PROPERTY VALUATION SYSTEM

Mass appraisal of the property values is carried out through a complex information system of mass appraisal (Computer Assisted Mass Appraisal – CAMA). Each of the components of this system are interconnected and together they form a system for mass property valuation. This system is a subsystem of the Geodetic Cadastral Information System that is connected to other subsystems of the Geodetic Cadastral Information System, such as the Real Estate Cadastre subsystem.

As already mentioned, it is essential that all immovable properties are registered, and all prices verified in the accurate and complete datasets. In this process, using prices from previous years implies temporal adjustment of prices, as well as using methods for comparing social and economic parameters. Extreme and unrealistic prices are rejected, as well as transactions that do not represent an open market (sales between legal entities, sale of property by municipal administrations, state administrations, auctions, etc.). Value zones are determined for each real estate submarket individually. The mass appraisal is done through the development of a real estate valuation model, which is determined according to the specifics of each individual real estate submarket on the territory of the Republic of Serbia.

To achieve given goals, a large amount of data is needed to assess the value of real property, and this data is collected from a variety of sources. Access to information on the location and characteristics of real property is a key component of an effective valuation model. Therefore, appropriate links are needed between public registers that have information on real property. The data sources for the real property valuation model are the Real Estate Cadastre (including cadastral map), the Real Estate Price Register and the Central Register of Planning Documents. In addition, alternative data sources can be used. All data from sales contracts are entered into the Real Estate Price Register. These are data for the identification of transactions (certification authority, number and date of certification), data on the price from transactions (contract date, amount, currency, unit price), data on parties (name and surname, personal number, place of residence), data on the type of the transaction (land, buildings, parts of buildings, mixed), basic data on real property (type of real property, area, share in transaction) and additional data on real properties related to their characteristics at the time of transaction that are required for market analysis. An important factor in the assessment is also urban planning, possibilities and limitations of construction, current and planned land use. Such information may be retrieved from the the Central Register of Planning Documents.

Figure 1 shows the overall architecture of the system for mass valuation. The main components of mass appraisal system are shown on the left part of the Figure. Real Estate Cadastre system and its main components are shown on the right. Both systems are the subsystems of the overall Geodetic Cadastral Information System, and they are linked in the sense that the Real Estate Cadastre provides relevant data for mass valuation and the results of mass valuation are then recorded in the Real Estate Cadastre in return. The system for mass appraisal (CAMA) consists of three main components. One of them is a Real Estate Price Register that stores data from the certified and verified contracts, additional questionaries filled by the officials and data from the Real estate cadstre retrieved via Web service. The other component is the system for the data processing that includes extraction, classification,

verification, and adjustment of data that will be used to train property valuation models. Finally, the developed models for property valuation are stored in the Register of property valuation models, which are then used to calculate the value of each individual property and record it into the Real Estate Cadastre.

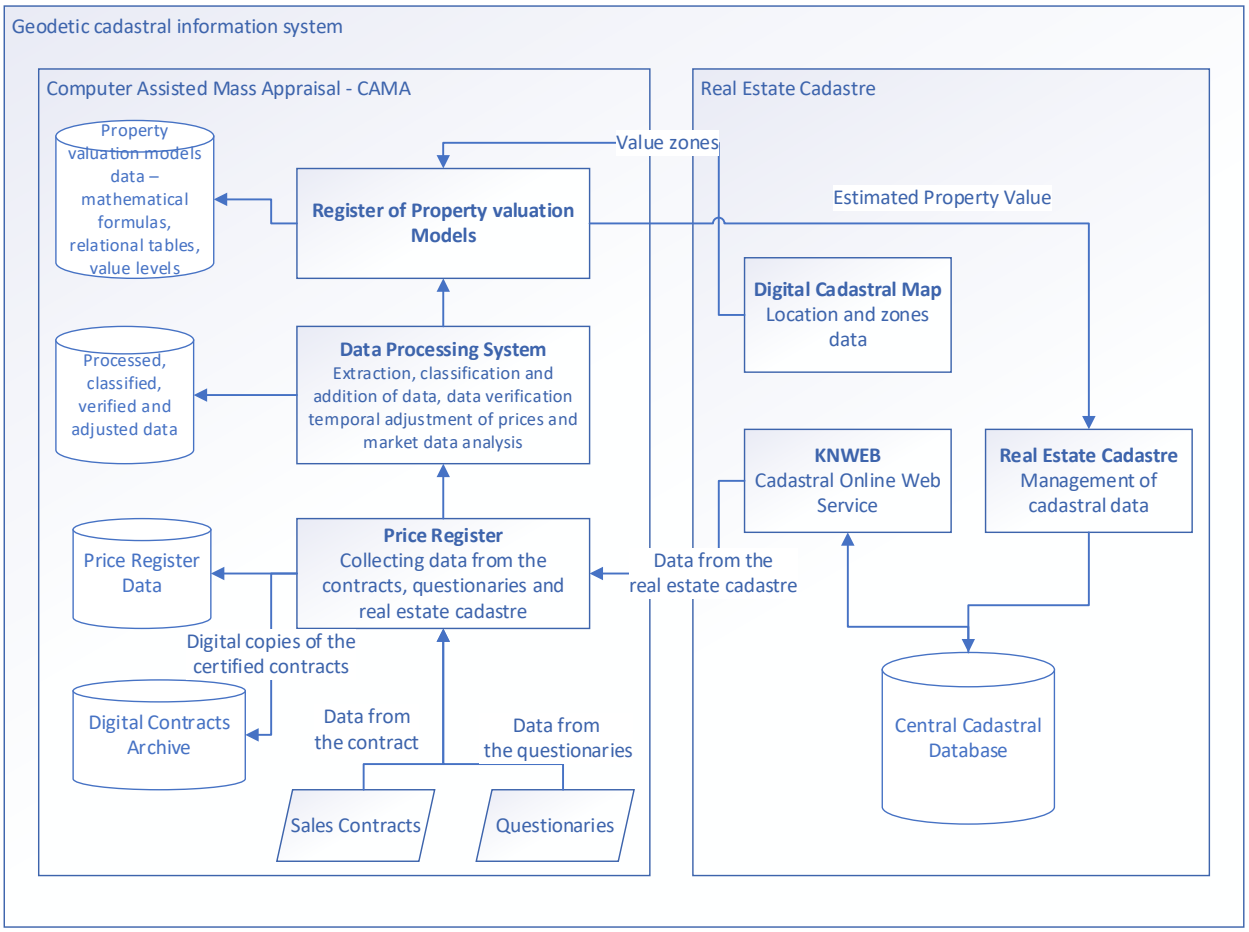


Figure 1. The overall architecture of the system for mass appraisal

3. EXTENDED LADM BASED PROPERTY VALUATION MODEL

Based on the developed Serbian LADM profile (Radulović et al., 2017) and LADM Valuation Information Model (Kara et al., 2019; Kara et al., 2021), a data model for the property valuation in Serbia was developed in our previous work (Radulović et al., 2022). The model was developed for the purpose of individual property valuation. In this paper, we extended the previously developed model to support mass valuation. Figure 2 shows an extended property valuation model. Mass property valuation model, represented by the class RS_VM_MassAppraisal is a system of expressions, tables and values used in mass assessment to systematically calculate the estimated values of a large number of immovable properties within one real estate submarket (RS_VM_ValuationUnitGroup). Real estate sub-market is a part of the real estate market where a specific type of properties

(RS_VM_ValuationUnitGroupType) is traded (such as agricultural land, condominiums, business premises, etc.) for which a certain group of market stakeholders are interested. Specification of a model for property valuation implies construction of a model by selecting factors of supply and demand, according to the theory of real estate economics, property valuation theory and real estate market analysis. Calibration of a property valuation model is a determination of coefficients in the model by statistical testing and, most often, by the method of multivariate regression analysis. Property valuation model is represented by RS_VM_ValuationModel class.

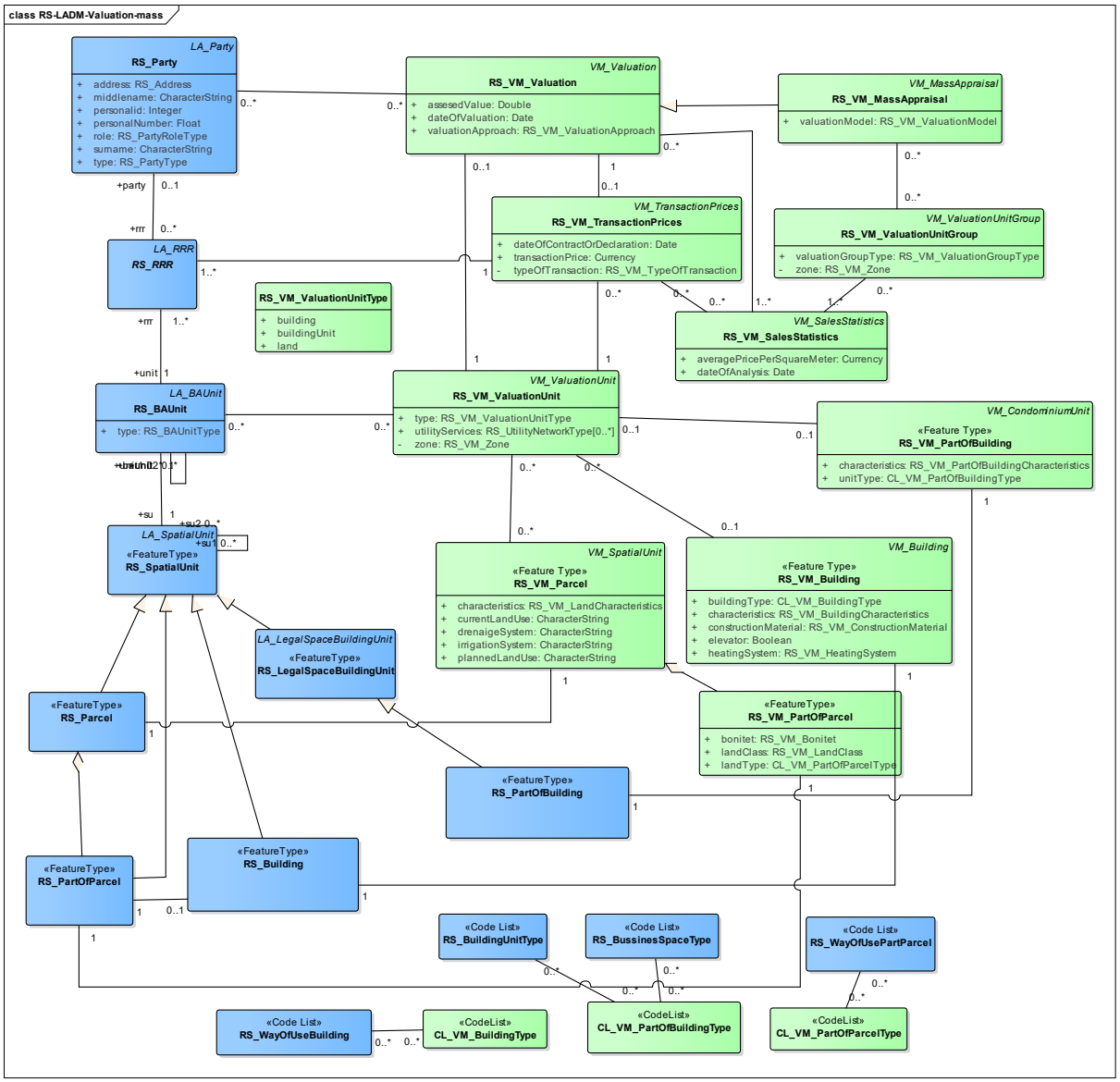


Figure 2. Extended property valuation model

Characteristic immovable property (also represented by VM_RS_ValuationUnit class) is the most frequently represented immovable property in the set of existing properties, as well as in the set of traded properties on in the territory of the Republic of Serbia, which is determined for each real estate submarket. Value zone (RS_VM_Zone) is an area in which characteristic

immovable properties have approximately the same unit price (price per unit of area or other established unit of real estate). Zone boundaries are set according to a set of rules, characteristic real estate and prevailing prices, because as a rule, locations do not exclusively contain prices of one value interval, even when it comes to real estate of the same characteristics. Value zones with average prices of characteristic real estate show the basic characteristics of the real estate market. Denser or smaller zones appear in parts of the country with an active and attractive market. Areas with a small number of sales and low prices characterize zones that cover larger territories. Value level is one of the measures of the central tendency of realized prices for characteristic real estate within the value zone. Relational table is a table that describes the difference in the value of any property and the characteristic property and serves to represent the coefficient values of different factors in the property valuation model. Ratio study is a comparison of estimated property value obtained by the system of mass valuation with realized prices on the real estate market.

Immovable properties that are registered in the Real Estate Cadastre, for the purpose of mass valuation are classified into the types and subtypes according to Figure 3. Three main types of properties are land, buildings and building units which are further subtyped by the way of use for the purpose of valuation. Code lists for the way of use in the Real Estate Cadastre and valuation system are not the same but are related which is shown on Figure 4. Table 1 expresses this relationship in the example of mapping of code lists and codes between mass valuation system and Real Estate Cadastre. This is only an excerpt of the entire mapping.

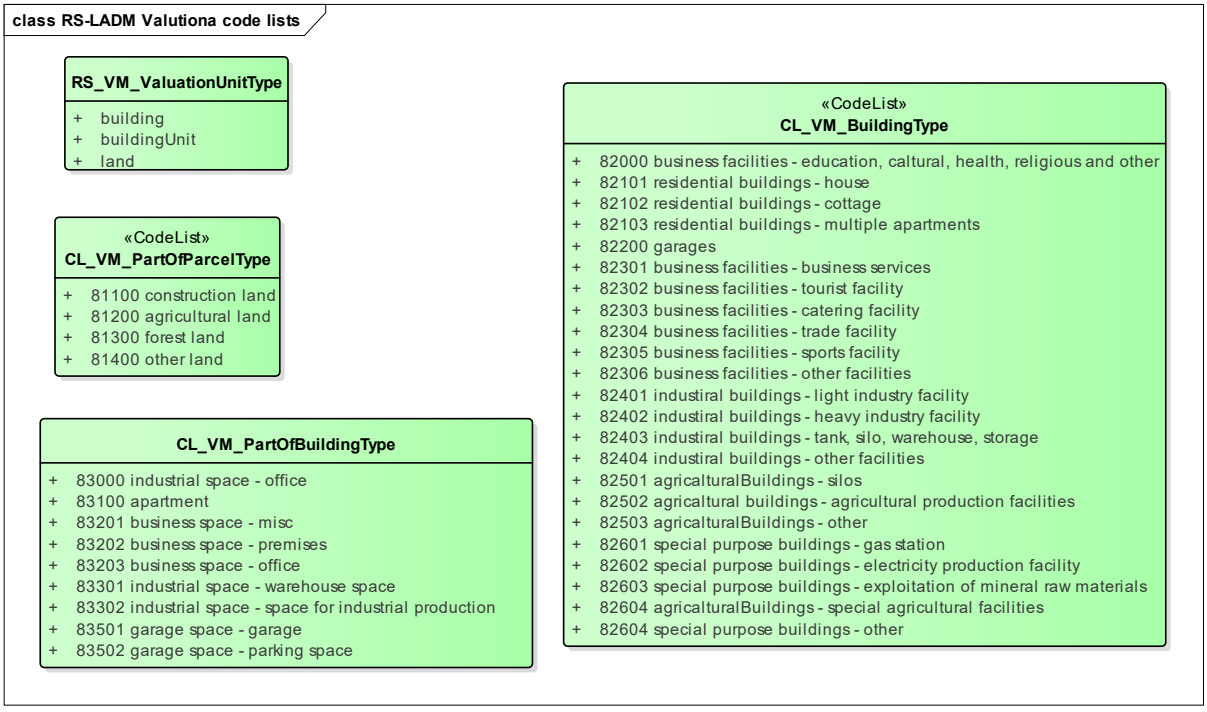


Figure 3. Property type code lists

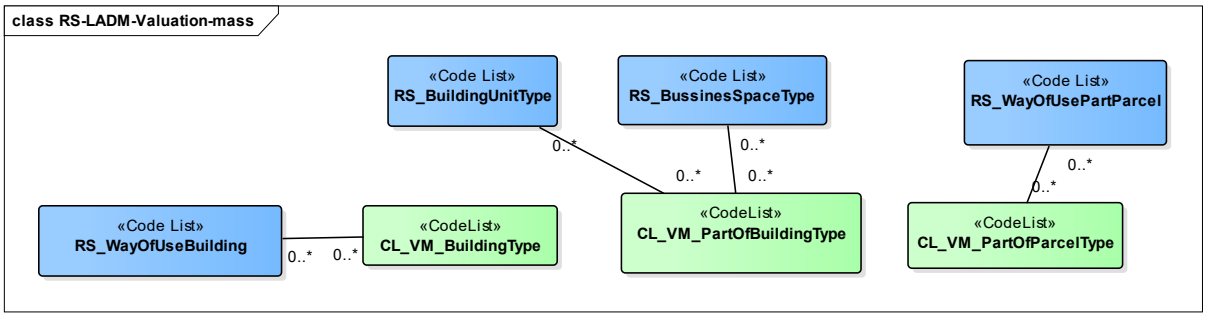


Figure 4. Mapping of code lists and codes between mass valuation and real estate cadastre

Table 1. Mapping of code lists and codes between mass valuation and real estate cadastre

CAMA				Real estate cadastre	
	Type	Subtype	Code	Code	
Buildings	Residential building	House	82101	10014	Family residential building
				10094	Family residential building - part
		Cottage	82102	10015	Cottage
				10095	Cottage - part
		Residential building with several apartments	82103	10010	Residential building for collective housing
				10090	Residential building for collective housing – part
				10030	Residential and commercial building
				10039	Residential and commercial building – part
Building units	Condominium		83100	3001	Condominium
	Garage space	Garage	83501	3003	Garage
		Garage space	83502		
	Business space		83201	3002	Business space
				3992	Business space – general purpose
				3412	Business space for public garage
				3552	Business space for sport
Land	Construction land		81100	1	Urban construction land
				2	Land in a construction area
				3	Construction land outside of construction area
				8	Other construction land in public or private property
	Agricultural land		81200	4	Agricultural land
	Forest		81300	5	Forest land
	Other		81400	9	Other land

Figure 5 shows classes and code lists that comprise property characteristics/features that may affect its value, and therefore can figure as a parameter in the model.

Figure 6 represents data that is extracted from the purchase contract and entered into Real Estate Price Register. Collection of this data is crucial for the development of the property valuation models.

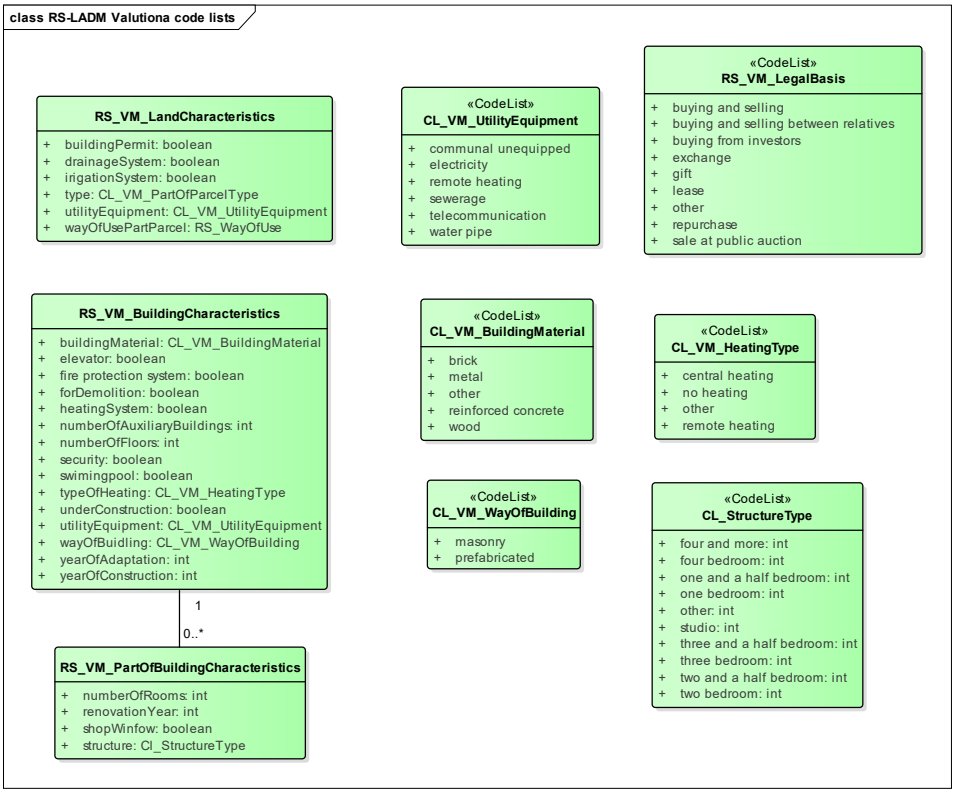


Figure 5. Property characteristics/features that affects its value

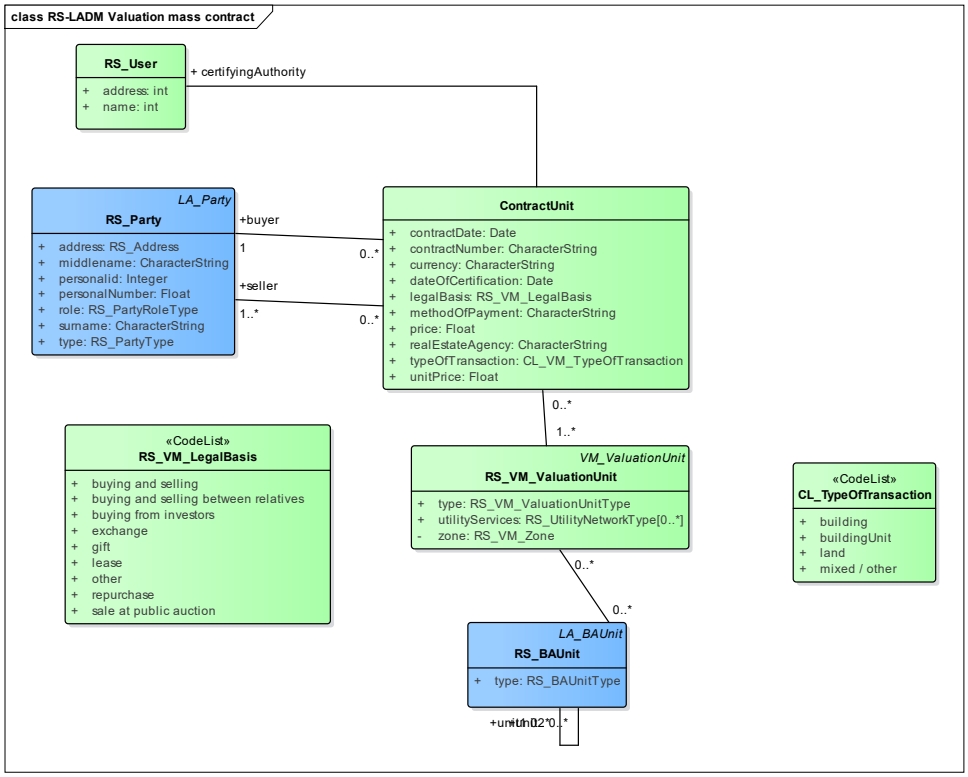


Figure 6. Data related to a single property transaction extracted from purchase contract

4. THE PROCESS OF MASS VALUATION

The mass property valuation system of real estate value consists of four subsystems (components) that are managed as interconnected information systems (Figure 7):

1. Collection of data for evaluation and data from the real estate market;
2. Processing of market data through verification, selection and analysis;
3. Defining the real estate valuation model (zone, formula, tables);
4. Calculation of real estate value.



Figure 7. The process of mass valuation

Spatial analyzes of market data include the presentation of prices and other market data on graphical bases, based on which analyzes are performed using various analytical approaches. This type of analysis is made possible by the previous location of the sale according to the location of the real estate participating in the transaction. Spatial analysis define value zones for the entire territory of the Republic of Serbia.

Mass assessment of the values of immovable properties includes general assessment of a property values and determination of values of the individual immovable properties registered in the Real Estate Cadastre based on data from general assessments of the property values (Figure 8). The general assessment of real estate value includes data collection, data processing, and defining a model for property valuation. Determining the value of individual properties includes calculation of the property value and entering data on the property value in the Real Estate Cadastre.

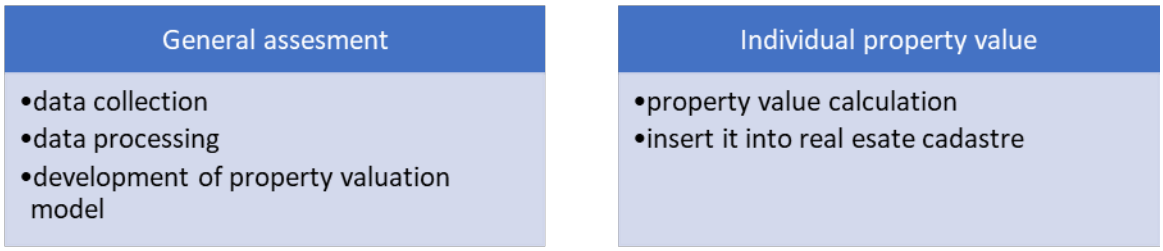


Figure 8. Mass assessment steps

4.1 Data collection

Data necessary for the mass property valuation are collected through the Real Estate Price Register. Records of real estate market prices serve to collect data from the real estate market and are kept in the Real Estate Price Register. The register consists of a database and a digital collection of contracts. Real Estate Cadastre organizational units are obliged to enter data in the Register upon receipt of the original or copy of a certified contract from the authority responsible for contract certification.

In the Register, data from real estate sales contracts and real estate lease contracts, real estate data from the Real Estate Cadastre database, as well as additional data taken from the questionnaire for registering real estate sales, are entered. Real estate data contained in the Real Estate Cadastre database is downloaded through the web service of the central real estate cadastre database. Questionnaires are filled out by legal subjects of real estate transactions when submitting a request for registration of a change of owner of rights to real estate. Upon data entry, digital copies of the documents are stored in the document management system.

Data on individual purchases and sales of real estates from the Register are published online, namely: type and subtype of real estate traded; area of traded real estate; transaction date; price currency; amount of the price. Reporting on the real estate transactions is done upon requests of the obligated parties, such as bankers, lawyers, appraisers, real estate agents, etc. The subject of the request may be data from the Register on purchases and sales related to one type and subtype of real estate, realized in a certain area, that is, location, in a certain period.

4.2 Data processing

The processing of data on real estate transactions is carried out in the system for processing data on real estate transactions and includes the extraction, classification and addition of data from the Register, verification of registered data, temporal adjustment of prices and analysis of market data. The system for processing data on real estate transactions consists of an application and a database into which the necessary data from the Real Estate Price Register database are periodically transferred. Extraction, classification and addition of data from the Register is performed once a month, from the first to the fifth day of the month for contracts registered in the previous month. It is done by the internal RGA office for mass valuation. Temporal adjustment of prices and analysis of market data are performed at least every three years. Data processing includes the following steps:

1. Extraction, classification and addition of data from the Register
2. Verification of registered data
3. Temporal adjustment of prices and analysis of market data

Extraction of data is done by separating: purchase and sale of land of the same type; purchase and sale of one building with an associated parcel; purchase and sale of a separate part of the building with the associated right on the land on which the building is located. Separated data on real estate transactions are then classified according to types of real estate grouped into real estate submarkets, according to code list in Figure 3. Addition of the data on traded immovable property from the Register is done by linking it to the data of the central database of the Real Estate Cadastre and the Digital Cadastral Plan, as well as to the data of the central database of the Address Register. It includes coordinates of the traded real estate, number of floors of the building, the floor number, number of rooms, restrictions, etc. Data from the Register is updated automatically, most adequately through the use of Web services.

Verification of registered data on real estate transactions is carried out to determine and improve the quality of registered data for the analysis of market data. Quality transactions are those with accurate and complete data on traded real estate, which represent transactions on the open market of real estate under conditions of fair sale, when the buyer and seller are

independent and unrelated, informed and act conscientiously and thoughtfully, and assuming that there is no undue influence on the price. The process of verifying registered data includes assessment of the reality of the price specified in the contract, assessment of whether the price specified in the contract belongs to an open and competitive market, and final assessment of the quality of real estate transaction data for the analysis of market data. The assessment of the reality of the price specified in the contract is carried out by comparing the price of individual transactions with the prices of realized transactions for the same type of immovable property within the corresponding value zone and by field inspection. A price that does not exceed the value interval of the corresponding value zone by more than 10% is marked as realistic. If this is not the case an inspection on the ground can determine that there is an undue influence on the price and it is marked as unrealistic. If in the corresponding value zone it is established that there is more than 50% of realized sales whose price is considered unrealistic, then a new value zone is formed for that area. The final assessment of the quality of registered data for market data analysis is performed after verification. Quality data on traded real estate is data that is complete, accurate, with a realistic price that meets the conditions of an open and competitive market.

Temporal adjustment of prices is the correction (decrease or increase of the amount) of realized real estate prices for changes in market price levels that occur after the real estate transaction date. Temporal adjustment of prices is carried out for each individual real estate submarket. Several zones can be established if the price indices in different areas differ by more than 20% for agricultural land and 8% for other types of immovable property. For the purposes of temporal adjustment of prices, the realized prices are classified according to the date of transaction by equal time intervals within a three-year period. The time intervals are quarters, half-years and years, and which of them will be adopted for the temporal adjustment of prices depends on the number of transactions achieved in each interval and the relative difference of the measures of the central tendency of the unit prices of the adjacent temporal intervals. For the temporal adjustment of prices, the shortest time intervals are taken that have at least 50 realized transactions and for which there is a relative difference of the measure of the central tendency of unit prices between adjacent time intervals greater than 10%. If no time interval meets the condition, the temporal adjustment of prices is done according to the annual time interval. Temporal adjustment of prices is carried out by adjusting prices from time intervals in the observed three-year period, using the price index, to prices from the last time interval. To calculate the price index, measures of the central tendency of unit prices from time intervals are taken.

After data processing, analysis of market data is carried out to determine the factors that influence the market value of a property. The minimum properties for each real estate submarket, each comparison unit and for each statistical analysis is 50.

5. PROPERTY VALUATION MODEL

Defining the property valuation model for the properties of the real estate submarket is done in the information system of the register of property valuation models. The process of defining the model is carried out in a cycle of at least three years. For each individual real

estate submarket, a property valuation model is determined, which consists of mathematical formulas, relational tables and value levels. Determining a real estate valuation model is a process that includes the model specification; model calibration; testing and adjusting the model and model evaluation.

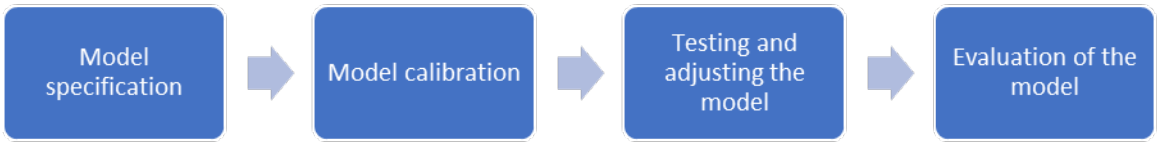


Figure 9. Process of determination of property valuation model

Model specification is the selection of factors for the initial model from the group of factors that, in accordance with market data analysis, have been determined to have a significant impact on property prices. The basis of each model is the characteristic property, which is determined by defining the values of selected factors in the model. After defining the characteristic property, which is a typical representative property, minimum and maximum prices are adopted that define the value range of such property in the territory of the Republic of Serbia. The range of values of characteristic property is divided into smaller intervals of values, whose measures of central tendency do not differ by more than 30%. Value intervals are indicated by value levels. Based on a series of value levels and spatial analysis, value zones are created, whereby each of the value zones is assigned to a certain value level.

By selecting the factors, an additive or multiplicative mathematical formula is formed, as follows:

$$V = V_0 + a_1X_1 + a_2X_2 + \ldots + a_nX_n \quad (1)$$

where:

- V – estimated market value,
- $X_1, X_2, \ldots, X_n$ – factors that figure in the model (n is the number of factors)
- V_0 – the value of the value level (it is determined according to the belonging of the property to a specific value zone)
- $a_1, a_2, \ldots, a_n$ - coefficients of the factors in the model.

Certain specific factors that rarely occur and do not affect all real estate of the same type (such as the slope of the land, a high degree of dilapidation of the building or noise due to proximity of the highway), which have an impact on the price over 10%, can be included in the mathematical formula and indirectly determined.

Relational tables are formed based on the formula (1) and contain all real estate categories for selected factors and the corresponding factor coefficients obtained on the basis of multi regression analysis. Determining the coefficients of relational tables is called model calibration. For the purposes of creating relational tables, the value range of the selected factors is divided for all immovable properties of the same type on the territory of the Republic of Serbia. Relational tables can refer to a maximum of two selected factors.

After the specification and calibration, models are tested with verified sales from the corresponding market, which were achieved after the observed three-year period. If these are not available, the verified sales from the observed three-year period, which were included in the market data analysis, are used. Testing is performed within value zones with the same value level, by checking whether the result obtained by applying the following formula weighs 1, i.e. deviates from 1 to +/- 20%:

$$\frac{\sum_{i=1}^{n}\frac{Vi(t)}{Ci(t)}}{n(t)} \quad (2)$$

where:

- Vi(t) – value obtained from the model for transactions from testing,
- Ci(t) – the price realized on the market for transactions from testing,
- n(t) – number of real estate transactions that entered the testing,
- i - represent each individual transaction from 1 to n.

Model adjustment is the change of previously specified models by repeating the previously described procedure if they do not meet the condition (3) during model testing. The adjustment of the model is repeated until the condition (3) is reached, and the obtained value that satisfies the condition is called model reliability. The model that meets the condition is considered the final model.

Determination of the property value and inserting it in the Real Estate Cadastre database is done after the final model is developed. The system for determining the values of individual properties consists of an application and a database. In this system preparations are made for calculating the market values of individual immovable properties, and then calculating and entering value data into the information system of the Real Estate Cadastre. Preparations for calculating market values for each immovable property registered in the Real Estate Cadastre include determination of classification division, submarket, value zone, value level and relational table, and calculation of factors that figure in the model (Figure 10).

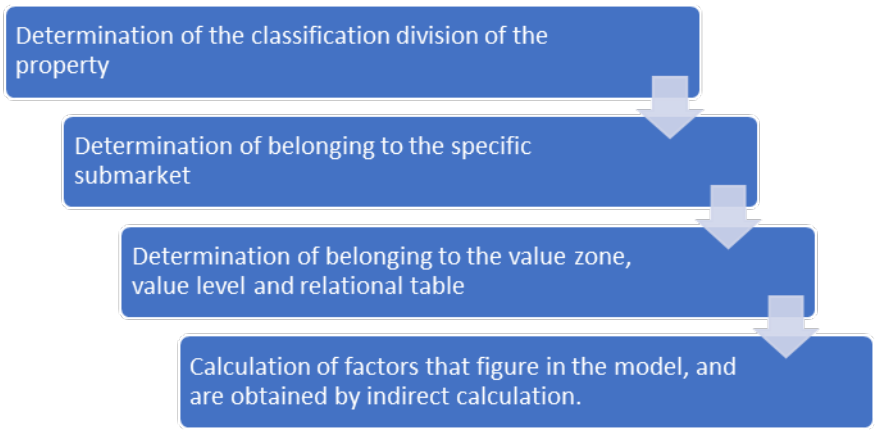


Figure 10. Preparation for the calculation of the property value

Determining the value of an individual immovable property implies calculating the value based on the final model and entering that value for each individual immovable property registered in the Real Estate Cadastre. Determining the value of each individual immovable

property is carried out in a cycle of at least three years, as well as at the time of registration of a new immovable property or changes to the registered immovable property in the Real Estate Cadastre. A change in a registered real estate that causes a redetermination of the value of an individual real estate is any change that includes the characteristics/features of the real estate that participate as factors in the model. Value to the property can be assigned if additional data has been previously collected for all registered immovable properties. Data on the final models are published online, with value zones, value levels and tables.

6. CASE STUDY FOR THE CITY OF NOVI SAD

Application of multiparameter regression in mass real estate valuation will be shown on the example of real estate valuation in the part of the cadastral municipality Novi Sad II (Figure 11). Cadastral municipality boundaries are shown on the left side of the Figure. Real Estate Price Register data that was used for the calculations is shown on the right side of the Figure. The sample that was taken to determine the influence of parameters on the market value of real estate includes 50 apartments, the area between 26 m2 and 130 m2, which is the minimum for mass appraisal, according to the rulebook.

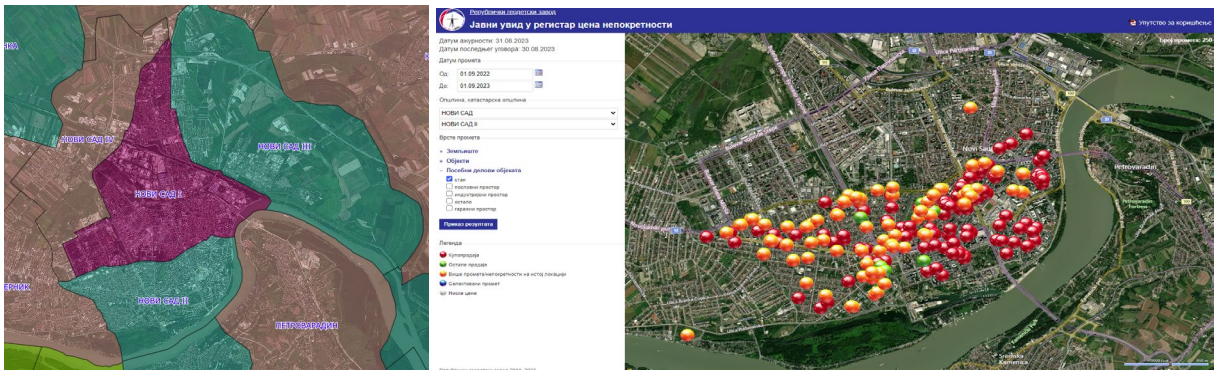


Figure 11. Property valuation for cadastral municipality Novi Sad II

We created two examples for determining the price of the apartments. The first example uses data available on the Real Estate Price Register web site. This site only provides the basic data about traded real estate which includes parameters such as the price from the certified and verified contract, area, whether it is an old construction or new construction or purchased from the legal entity (investor) and whether it has garage or parking space. Difference between old and new construction is mainly different building style and design and different way of construction, and they are usually built before and after the year 2000. New constructions are generally considered more appealing to the buyers. Excerpt of such data is shown in Table 2.

Table 2. Basic parameters

Price (EUR)	Area (m2)	new construction / old construction	From the investor	Garage/parking
74000	39	0	0	0
113000	58	0	0	0
134000	86	0	0	0

100000	47	0	0	0
110000	55	0	0	0
140400	78	1	0	0
106700	51	0	0	0
105000	60	0	0	0
130000	72	0	0	0
82026	46	1	1	1
140170	74	1	1	1
70000	28	1	0	0
75800	29	1	0	0
71300	30	1	0	0
153000	58	1	0	1
71200	30	1	0	0
115000	54	0	0	0
143000	66	0	0	0

The second example uses data obtained from the real estate agencies. Datasets of real estate agencies provide much more data about properties that are on market, but they show the price offered but not received. The final price is usually about 10% lower. The parameters used for evaluation in this example are area, age, storey, roominess, total number of floors, elevator (yes/no), terrace (yes/no), number of bedrooms, bathroom number, parking lot/garage, basement, registration/legalization. All these parameters contribute to the value of the apartment and the price can be better estimated. Excerpt of such data is shown in Table 3.

Table 3. Additional parameters

Price	Area m^2	Age (years)	Storey	Number of rooms	Number of floors	Elevator	Terrace	Parking /garage	Furniture	Registered
97.850	34	13	2	1.5	5	1	1	0	0	1
79.250	27	2	4	0.5	5	1	0	0	1	1
90.800	42	17	6	1.5	6	1	0	0	0	1
87.550	35	13	0	1.5	6	1	1	0	0	1
189.000	79	13	1	3	5	1	1	0	0	1
164.800	60	15	2	3	6	1	1	0	0	1
172.500	91	18	1	3	6	1	1	1	0	1
69.900	26	10	3	0.5	3	1	0	0	1	1
199.800	85	15	2	3.5	5	1	1	1	0	1
134.000	52	48	1	2	4	1	1	0	1	1
106.500	47	24	2	2	5	1	1	0	0	1
216.300	92	18	1	3	3	1	1	0	0	1
175.100	67	14	1	3.5	5	1	1	0	0	1
342.000	130	15	3	4	4	1	1	1	1	1
133.900	53	17	0	2	5	1	1	0	1	1

The results are shown in the Table 4. For the calculation we used MRA in scikit-learn python library. Calculated r2 score for the first example is 0.87964, while in the second example it is 0.9834. The second model has a better score and is more consistent, but its accuracy is diminished by not having the verified prices. The last column represents values determined by the second model, which are advertised values, with only area as a varying parameter, while all other are considered the same (the calculation is done for the typical apartment in a new building on the second floor out of five, without garage or parking place).

Table 4. Result - predicted prices in EUR

Area m^2	Old building	New building	From the investor	From the investor with garage	With additional parameters
30	67186	72145	76225	78042	91527
50	97397	102355	113057	119652	142868
65	118617	125013	126764	133359	168411
80	142325	147966	150472	157067	211237
95	166032	171673	174180	180774	236780

7. DISSCUSSION

By analyzing the current system, we propose the following recommendations for the improvement of the CAMA system to facilitate mass appraisal in timely manner. First, a thorough LADM based conceptual model of the domain and services for mass property valuation should be developed, tested and adopted by the official authority (RGA). The domain model would enable integrated data management. Since it is based on LADM country profile and LADM valuation model it would provide the system to be better interlinked with the cadastral system which is important for mutual data exchange. To enable data interoperability, service-oriented architecture is proposed, based on the developed service model. The service model should provide detail specification of actors and interaction among subsystems in Geodetic-Cadastral Information System including CAMA and Real Estate Cadastre, followed by specification of services in the system that would provide the basis for the implementation of Web services. Such services would facilitate automatic exchange of all relevant and accurate data in the timely manner and avoid error prone manual work.

Furthermore, a database of the developed valuation models for each submarket should be clearly defined and developed. In this regard, a list of all parameters that affect the value of a property should be precisely determined and its coefficients calculated for each relevant period. It is also suggested to analyze the possible use of other Automated Valuation Models - AVM (Doumpos et al., 2020), which are AI based models concerning real estate market analyses and valuation, among which MRA is the oldest and most common one, but may experience certain weaknesses such as excessive collinearity, which can lead to lowered effectiveness of the valuation (Jahanshiri et al., 2011). There are numerous methods proposed in the literature that can improve accuracy of the property valuation such as spatially constrained multivariate clustering analysis (Sisman, and Aydinoglu, 2022), ridge regression model, k nearest neighbors regression and random forest regression algorithm on categorical variables (Gnat, 2021), hedonic methods for residential land values (Bourassa and Hoesli, 2022), Bayesian model average for urban residential land value (Quang Cuong, 2023), eXplainable Artificial Intelligence (XAI) methods for the mass appraisal of residences (Iban, 2022). Yilmazer and Kocaman (2021) showed that random forest approach outperforms conventional MRA in mass appraisal of real estate properties in highly complex urban environments. Selection of characteristics / features that mostly influence property values can also be automated using different approaches such as PCA or AHP (Yalpir et al., 2021).

Three-dimensional (3D) information can also be used to better estimate and explain values of property units (Kara et al., 2020). 3D models and 3D datasets are not widely used in this domain, although valuable information may be extracted from them, such as property

characteristics that influence its value. Using 3D information Web-based visualisation and dissemination of 3D valuation units and groups may be achieved (Kara et al., 2023). Using 3D BIM data for the purpose of valuation to determine quality of the properties is proposed by Radulović et al. (2023).

8. CONCLUSION

In this paper we analyzed the current system for mass property valuation in Serbia and suggested future recommendation for improvements. For the accurate property valuation, it is essential that all relevant data is available and up-to-date. In this regard, it is crucial to develop and adopt a comprehensive conceptual model, which will enable better organization of the data in the databases. Since mass property valuation information system is dependent on the cadastral information system it is advisable that both conceptual models are interlinked. Therefore, the use of developed Serbian LADM profile and property valuation model based on LADM Valuation Information Model are proposed. Based on this conceptual model, service model should be developed to facilitate automatic data exchange. A detailed and reliable development of real estate valuation models is essential for each submarket that has its on specifics and market trends. In this regard, other methods and AI based model are worth exploring that in the recent literature are showing more accurate results, than the traditional MRA.

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3D Cadastre Potential Assessment – A Trinidad and Tobago Property Valuation Perspective

Charisse GRIFFITH-CHARLES, and Sunil LALLOO, Trinidad and Tobago

Key words: 3D Cadastre, LADM, Property Valuation, Trinidad and Tobago

SUMMARY

Each country must assess its own potential for attaining a 3D cadastre in its land administration. The assessment can be done on several criteria among which are the state of its legislation supporting the establishment of the cadastre, the strength of its current spatial data infrastructure, the registration structures in place, and the organisational capacity of its existing land administration. This case study used these assessment criteria to examine the potential of Trinidad and Tobago for attaining a 3D fiscal cadastre for its property valuation.

The potential for development of the 3D cadastre in Trinidad and Tobago is relatively high among developing countries given the country's previous oil and gas income security which drove its comparatively advanced level of technology use among regional countries, as well as the presence of research capacity at the University of the West Indies.

Legislation, technical data infrastructure, registration processes, and organisational capacity are the areas assessed to conclude that the potential for the development of the LADM valuation extension is relatively high with some key suggestions for implementation of the process. The literature suggests possible structures and processes as well as problematic issues for taking this forward.

The paper concludes that the value component of the 3D cadastre is not well supported by the land legislation but the country already has a sound organisational mechanism in place for data acquisition through the system of valuations done for the various taxation purposes – stamp duty and property tax. The legislation needs to address the fact that interests in land – both formal and informal need to be accommodated in the legal registry in order for the valuation databases to be comprehensive and integrated. Additionally, individual real estate interests on common lands (condominiums) need to be identified as separate legal assets to more accurately reflect the way in which these properties are held, along with the capital values of the individual rights.

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1. INTRODUCTION

Previous research has investigated the various components of a 3D cadastre establishment process. In some cases such as Paulsson and Paasch (2013) the areas of legal, technical, registration and organisational in the literature were reviewed. Categorisation into these thematic areas attempts to subdivide the broad issue of 3D cadastres into assessable components. A similar thematic categorisation can be used for assessing a specific country's potential for establishing a fiscal cadastre. There is a need for 3D cadastres in the country of Trinidad and Tobago, given the densely populated high-income condominium developments as well as the high density low-income unplanned developments in insecure tenure (Griffith-Charles 2011; Griffith-Charles and Sutherland 2020). However, despite the demonstrated need for land administration data for managing the equitable allocation of land, implementation of recommendations is slow in coming. It is hoped that recent inroads into the development of a property tax database would indirectly drive support for the development of the 3D cadastre with at least a valuation module based on standardised LADM structures. This paper investigates the existing potential to develop the 3D cadastre with specific focus on the valuation component across the different bases of property values and tenure continuum. Several aspects are described including the legislation that supports the construction of the valuation component as well as lacunae that need to be addressed so that valuations of all properties can be legally recorded and accommodated. The institutional processes are also assessed for the ability to create the 3D cadastre and the capacity for sustainability in the valuation component of the land administration is also assessed.

2. METHODS

Much of the data acquired for the assessment exercise was obtained from interviews with personnel at the Valuation Division or from examination of available laws and documents as well as public statements made on the assessment of properties exercise currently being conducted. These data were compared with extant situations in the literature in more developed societal contexts as well as theoretical models for development of a fiscal cadastre compliant with LADM requirements (Kara et al 2021; Cagdas et al 2016). While the thematic areas of legal, technical, registration and organisational were used previously to categorise components of a 3D system, as shown in Figure 1 (Paulsson and Paasch 2013) for this assessment of the fiscal cadastre the thematic areas of legal, technical and organisation were used instead as registration aspects fit neatly into technical processes.

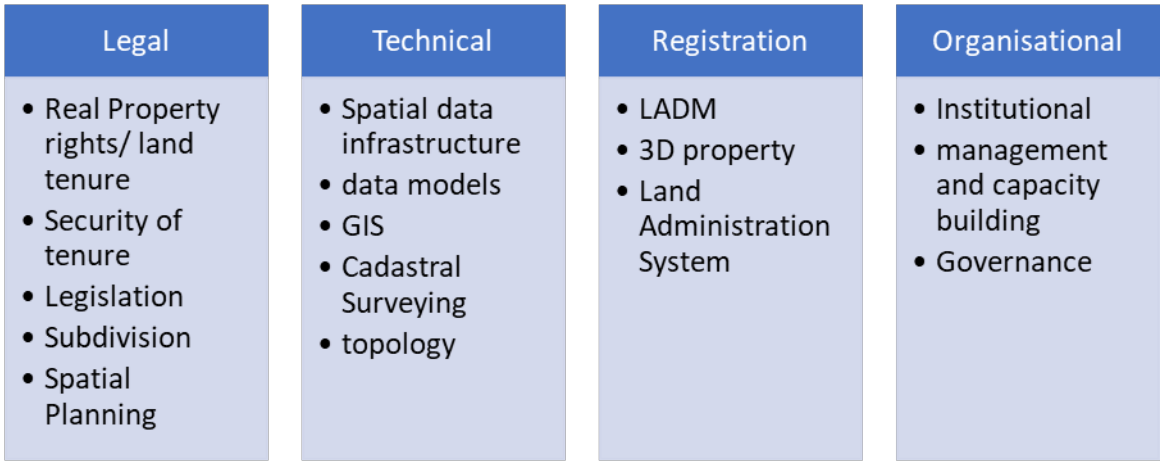


Figure 1 - Categories of Literature on 3D cadastres. Adapted from (Paasch and Paulsson 2023, 2)

3. LEGISLATION

The current valuation of land legislation in Trinidad and Tobago allows for the capture of multiple types of property value including capital value, depreciated replacement cost as well as Annual Rental Value (ARV), which is to be used for property tax assessment. The legislation also allows for the valuation of the interests of informal occupants who have no legal tenure and distinguishes this from the value of the interest held by the title owner. The legislation defines 'owner' to include occupiers or anyone holding the land in his own right. It also defines 'parcel' as any land held by an owner or possessor of land. These definitions therefore have the power to subdivide units of land in a different way than formal title processes. However, the land registry does not have legal support for recording documents that reflect informal occupation nor does it facilitate the recording of property values nor link to the valuation roll nor the cadastral database. Only formal registered land units held via deed documents or title certificate can be accommodated in the land registry. The Lands and Buildings Taxes Act No. 14 of 1920 gave way to the Property Tax Act No. 18 of 2009, which was amended in 2015 to waive the reintroduction of property tax, to allow for an overhaul of property tax so that income could be generated more readily to fund local government institutions and services. The Valuation of Land (Amendment) Bill, 2023, now seeks to amend the property tax law to support valuation and taxing of different types of land beyond residential as was previously the focus. The Bill also sets a base limit on property value at $TT 18,000 ($US2700).

There is also no legislation that directly addresses registration of condominium properties as individual properties, despite several attempts by the Parliament to pass relevant legislation. Of all new properties entering the market in the recent decade, condominium-type properties are the most prevalent. They include apartments, terraced housing (known locally as

"townhouses", duplexes and detached houses on the same parcel of land. As the property registration system is land-based, the lack of condominium legislation that recognizes individual property rights over the common land, means that individual titles cannot be registered. This gap requires a legal work-around using a head-lease system where freehold or head leases of the condominium complexes and land subdivisions are owned registered in the name of a company comprising all the individual owners whose shares in the company are represented by an individual unit to which they hold a leasehold interest. Their individual interests are registered as sub-leases for a long term (usually 99 or 199 years). The value of their leasehold interests would only be recorded at the onset when the interest was conveyed. . It is unclear whether the freehold interest in the headlease would be assigned a value, despite the fact that this would likely be nominal. Nonetheless, the interest in the headlease is registered and captured in the valuation roll as a taxable entity onto itself.

4. TECHNICAL STRUCTURES AND REGISTRATION

If the establishment of spatial data infrastructures is not addressed in the legislation, the result would be a lack of interoperability and integration between the datasets as well as incomplete and inadequate information for decision making. The fiscal cadastre in progress is not required to be consistent with the LADM as the LADM does not yet accommodate a valuation module (Kara et al 2021). In addition, the unit used for the LADM is the legal juridical and not fiscal parcel which, for valuation databases may not coincide with the assessable property. In the Trinidad and Tobago case, the properties required to be assessed are the occupied units and not only the legal units that are part of the registry. To this end, the current valuations are being attached as attributes to the parcel centroid or any coordinate on the land, and parcels are defined as the occupied unit. This will cause a mis-match between the datasets unless discussions are held to decide on conceptual ways of integration. Figure 2 shows this mismatch where the large, single, state parcel, coloured yellow, lies next to a large, single private parcel, coloured blue, while many individually occupied houses pervade each parcel and can be assessed for property tax.

Figure 3 shows the public facing cadastral index to demonstrate how many parcels are not now captured and therefore how much of a challenge the Valuation Division would have in using this dataset as its foundation. The parcels to the east are defined, registered and captured in the database while the parcels to the west are not yet captured on the index even though they may or may not have been surveyed.

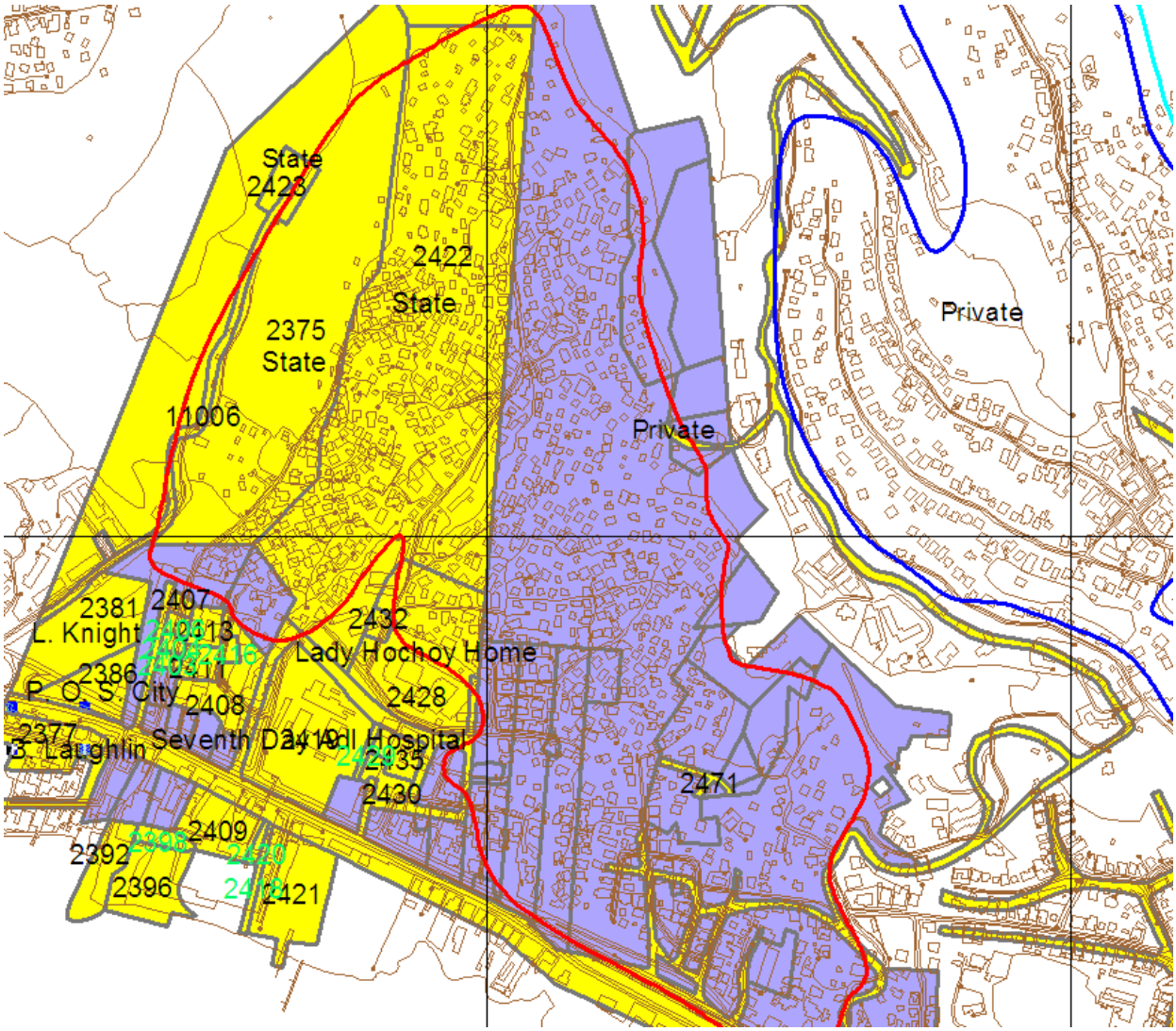


Figure 2. Mis-match between juridical parcel units and fiscal building units



Figure 3. Parcels on the parcel index are outlined in red while others are not yet captured

5. ORGANISATIONAL CAPACITY

Capacity is an issue that also needs to be addressed to ensure that data can be established and maintained in a 3D cadastre for Trinidad and Tobago. For property valuation data, public and private professionals provide input but it is the public officers who develop the tax roll without benefit of mass appraisal techniques. There is therefore not a comprehensive roll and updating annually is not possible. The potential for use of mass appraisal techniques for valuation for tax purposes can be assessed by examining the proportion of standard residential properties that have been mass produced in several communities in the country. The result is a significant and growing proportion of the existing residential housing stock. Local valuers resist the introduction of mass appraisal for fear of loss of jobs. However, the lack of homogeneity in real estate in Trinidad and Tobago, and the wider Caribbean region, would significantly inhibit the use of a mass appraisal method due to anticipated high variances arising out of the statistical tests. Very few studies, if any, are available to evidence precisions of individual valuations in comparison to mass appraised values. It was estimated, based on information from the national electricity company that there are some 400,000 residential properties in Trinidad and Tobago (Matthews 2023). However, the Valuation Division has already digitised 536,876 properties in Trinidad and 33,665 properties in Tobago for a total digitisation of 570,541 properties in the country after years of fieldwork data acquisition and verification of submitted documents from owners and occupiers. Data acquisition was begun in 2017 so the exercise has been six years in process. This does not take into consideration individual apartments and condominiums as these are planned to be entered on the valuation database in a later phase of the acquisition exercise. An updated estimate is closer to 600,000 properties. Despite the digitisation of the location of the properties the Government has stated that only 232,000 properties are completely ready for the property roll (Matthews 2023). The capacity of 250 field assessors was built in 2017 and 2019 by training from the University of the West Indies, St. Augustine, Department of Geomatics Engineering and Land Management to undertake faster and more efficient data acquisition. Beyond this, there is continued professional degree level training ongoing at the University for valuers. However, the institution needs to adopt mass appraisal techniques as these are developing higher precisions and quicker outcomes as a result of the input of mathematical models and assistive AI components (Kara, et al. 2023). In developed countries such as the Netherlands, where 9 million properties are valued annually (Kara et al. 2023), assistive mechanisms are used to quickly automate the process and maintain the data in a current form. At this rate and with this much capacity the valuation roll in Trinidad and Tobago has not yet been completed. Revaluing the entire dataset annually cannot therefore be envisaged. The Valuation Division does not disseminate individual or consolidated statistics on values nor is there an accessible and transparent valuation roll. More research and more open data can support the acceptance of more efficient ways of valuing and revaluing properties and reduce any corruption and fraud that may surround the property market.

6. DISCUSSION

A 3D Cadastre that integrates all land information in Trinidad and Tobago, would lack completeness if value is excluded. The impetus to roll out the new Property Taxation system is a promising starting point to acquire, categorize and store valuation data that would

enhance the cadastre and assist in land information management. The data acquisition and system construction process for the fiscal cadastre is better resourced at the moment as a result of the impetus to facilitate the property tax process. However the juridical base graphic data is insufficient to support the fiscal cadastre since valuations are less interested in intangible property boundaries but require dense information on physical amenities. While there are several gaps in the institutional framework that need to be addressed, these challenges are not unique or separate from the wider problems of land administration. It is therefore imperative that the valuation roll is considered in the development of the 3D cadastre in Trinidad and Tobago.

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BIOGRAPHICAL NOTES

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Land Administration Domain Model OGC Standards Working Group

Eva-Maria UNGER (Austria), Peter VAN OOSTEROM (The Netherlands), Abdullah KARA (Turkey), Scott SIMMONS (USA) and Christiaan LEMMEN (The Netherlands)

Key words: LADM, OGC, ISO, FIG, LADM implementation

SUMMARY

In February 2019 the OGC White Paper on Land Administration is published. This White Paper provides an overview of the land administration domain and relevant developments. It also proposes necessary actions for the design and development of an implementation standards. The document includes an overview of needs and requirements as earlier discussed during the various LADM Workshops.

During the closing session of the 2021 LADM/3D workshop (embedded in the FIG e-Working Week 2021) FIG expressed its commitment to collaborate with ISO and OGC regarding the implementation of LADM as an integral component of the standardisation efforts in land administration.

Currently, the LADM revision is ongoing and includes land registration, marine space geo-regulation, valuation information, spatial plan information. Further, enhanced support in cadastral surveying is proposed to be provided, through a comprehensive survey model. The new edition is multipart, part 6 is on a standard for LADM implementation. The development of this can be strategically aligned with the developments of the other parts of LADM edition II.

This paper serves as an initial step towards fostering a dialogue to promote the implementation of LADM. It emphasis the creation of a Land Administration Domain Model Standards Working Group Charter within the OGC. A draft charter is currently available for reference, along with insights from the 2019 White Paper. It is imperative to engage stakeholders from industry/business, government and academia in this development to ensure its success and relevance.

Land Administration Domain Model OGC Standards Working Group

Eva-Maria UNGER (Austria), Peter VAN OOSTEROM (The Netherlands), Abdullah KARA (Turkey), Scott SIMMONS (USA) and Christiaan LEMMEN (The Netherlands)

1. INTRODUCTION

In 2012, the first edition of the Land Administration Domain Model (LADM) is approved as an official ISO standard (ISO, 2012; Lemmen et al. 2015). LADM covers the 'information-related' components of land administration (LA) by providing a shared ontology and defining common terminology for LA. The representation of all tenure types is supported through the standard and it provides a solid framework for the development of 3D Cadastre and other LA components. The standard uses the term 'land administration' in a broad sense, including geographical spaces covering water, land and elements above and below the surface of the earth.

As an ISO standard, the LADM is subject to periodic revision, typically in a 6 to 10-year period aiming to meet upcoming user requirements, extend the scope of the standard, as well as revise the current edition. In 2019 it is agreed within ISO/TC211 that the second edition of the LADM will be developed as a multi-part standard, with experts being involved from academia, industry, standardization bodies and professional organizations across the world.

Currently, the LADM revision is ongoing (Lemmen et al., 2023), and among others, the missing functions of land administration in edition I are now added in the revised edition: valuation information, spatial plan information, and marine space georegulation. Further, enhanced support in cadastral surveying is proposed to be provided, through a comprehensive survey model. New types of spatial units are proposed as well as options for implementation of the standard are proposed to be included.

The Fit-For-Purpose Land Administration approach (FIG/World Bank, 2015; UN-Habitat, 2016) argues for cost-effective, time-efficient, transparent, scalable, and participatory data collection and management, including participatory surveying, volunteered land administration, and crowdsourcing. The approach is affirmed in the Addis-Ababa Declaration 'Geospatial Information Management towards Good land Governance for the 2030 Agenda', (UN-GGIM, 2016)[1]. The approach sets requirements for future Land Administration.

In June 2016 the Land Administration Domain Working Group is established[2] in the Open Geospatial Consortium - a consortium of companies, government agencies, and universities participating in a consensus process to develop publicly available geospatial and location-based services. Within the OGC the Domain Working Groups (DWGs) provide a forum for discussion of interoperability requirements and issues, discussion and review of

[1] https://ggim.un.org/documents/Addis%20Declaration%20Final%2022Apr2016.pdf
[2] https://ggim.un.org/meetings/GGIM-committee/6th-Session/side_events/Land%20Administration%20Working%20Group%20-%20UNGGIM.pdf

implementation specifications, and presentations on key technology areas to solve interoperability issues. The Land Administration DWG outlines activities related to land administration. Worldwide, effective, and efficient land administration is an ongoing concern, inhibiting economic growth, property tenure, protected environment etc. The initial membership of the Land Administration DWG is open to both OGC members as well as experts from outside of OGC. A critical aspect of the work of the Land Administration DWG is to learn about and document the requirements from the entire community.

In February 2019 the OGC White Paper on Land Administration is published. This white paper provides an overview of the land administration domain and relevant developments and proposes actions needed for the design and development of an implementation standards in this domain. The document includes an overview of needs and requirements as discussed by an inventory through an international group of experts during the LADM Workshop in Delft, The Netherlands in March 2017 and in Zagreb, Croatia in April 2018. Some of these needs recommend an extension of LADM.

The OGC White Paper on Land Administration proposes close cooperation between the Open Geospatial Consortium (OGC) and ISO, this is expected to accelerate these developments. Due to the Covid-19 pandemic, this proposal was not discussed further until the LADM/3D Land Administration Workshop in 2021 which was embedded in the FIG e-Working Week. During the closing session of that workshop FIG agreed to look for cooperation with ISO and OGC on LADM implementation (as part of the standard). This cooperation was given substance at the VII Croatian Congress on Cadastre and at the 10th Workshop on the Land Administration Domain Model held in 2022 in Dubrovnik, Croatia and during meetings of the Land Administration Domain Working Group at the OGC.

With the development of edition 2 of LADM well underway. This paper attempts to start the discussion on taking actions to advance the LADM implementation. At this moment a preparation and planning in alignment with the developments of the other parts of LADM is possible. The objective is to create a Charter for the LADM Standards Working Group within OGC. To accomplish this, a draft charter that is readibly accessible is used, along with references to the insights that were provided in the 2019 White Paper. The active involvement of stakeholders from business, government and academic sectors is imperative. Standardisation in Land Administration finds support and recognition in the Framework for Effective Land Administration of the United Nations Committee of Experts on Global Geospatial Information Management, UN-GGIM (2020).

In this paper chapter 2 offers a review of the current progress and planning related to the development of LADM edition II. Subsequently, chapter 3 presents a comprehensive background and context of ongoing developments, which serves as a basis for establishing the needs and requirements for land administration: Data acquisition, maintenance and dissemination. Chapter 3 revisit and summarises the insights from the OGC Land Administration White Paper. Following this, Chapter 4 discusses consideration and actions aimed at advancing the implementation of LADM. This is in line with the development of the OGC charter for the Standards Working Group on Land Administration. The paper ends with a series of recommendations outlined in Chapter 6.

2. STATUS OF LADM DEVELOPMENT

This chapter focuses on the structure of the second edition of the ISO 19152 LADM and its proposed operational capabilities, through the new parts that are currently under development. Six parts are currently under development, each part follows the ISO standardization process and is in fact a standard in itself. The parts of the second edition of the LADM are the following:

- Part 1 – Generic Conceptual Model
- Part 2 – Land Registration
- Part 3 – Marine Space Georegulation
- Part 4 – Valuation Information
- Part 5 – Spatial Plan Information
- Part 6 – Implementation Aspects

During the revision process, close collaboration with various FIG Commissions is being achieved, specifically, FIG Commissions 3 'Spatial Information Management' and 7 'Cadastre and Land Management' for part 2, Commission 8 'Spatial Planning and Development' for part 5 and Commission 9 'Valuation and the Management of Real Estate' for part 4.

Figure 1 presents the five out of six parts that are currently under development. The development of part 6 has not yet started. As noticed from the standards' titles, a new term "georegulation", with a wider meaning. The concept of georegulation is introduced, encompassing the delineation of geographical spaces in 2D, 3D, or 4D dimensions. This term is particularly relevant when referring to marine environments. As mentioned, standards should include a set of requirements that form the basis of the scope, and which are further used to specify an abstract test suite. The packages structure of the new edition is designed in a way that meets the requirements that have been developed during the revision process, see (Lemmen et al., 2023).

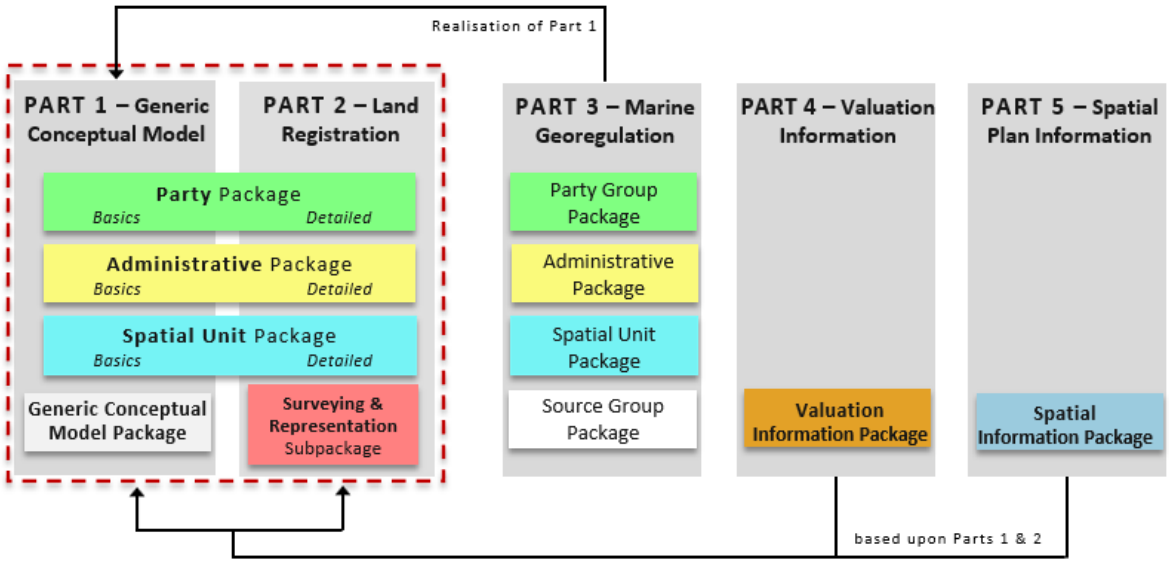


Figure 1. Parts 1, 2, 3, 4 and 5 of LADM Edition II that are currently under development

Part 1 is a high-level umbrella standard that supports all the other parts of the new edition of the LADM and provides an overview of all parts. The “Party”, “Administrative” and “SpatialUnit” packages are common packages in part 1, as well as, in part 2. For the common packages, in part 1 the fundamental notions are introduced, while the detailed description of these packages is included in part 2 (attributes, multiplicities of relationships and attributes). It is noted that part 1 will not only be backwards compatible with the previous version of the LADM but also with the IHO S-121 ’Maritime Limits and Boundaries’ standard (Beaupré et al., 2022; IHO, 2016) that will be used as basis for part 3.

Part 2 focuses on Land Registration and will be largely based on the first edition of LADM, with refinement and extension at the survey model, the 3D spatial profiles and semantically enriched code lists. Part 3 on Marine Georegulation harmonizes the description of Rights, Restrictions and Responsibilities in the marine domain, aligned with land concepts to provide seamless land/ marine LA.

Moreover, parts 4 and 5 have each been designed as a single package, both based on the definitions in part 1 and part 2. In part 4 the Valuation Information Package is introduced concerning valuation information used and produced in the context of LA, specifying the characteristics and semantics of valuation registries maintained by public authorities. In part 5 the Spatial Plan Information Package deals with spatial planning information and includes the planned land use (zoning).

Lastly, part 6 concerns the implementation of the standard. It is planned to propose a methodology for developing a LADM-based country profile, an abstract framework for representing LA workflows (processes), a metamodel for structuring and managing semantically enriched code list values, as well as support different encodings. In addition, Part 6 is expected to include the OGC API family of standards-compliant recommendations for the development of interoperable LADM schema-based information systems. Furthermore, the relationships between the LADM and the instruction guidelines for property measurement, such as the International Property Measurement Standards (IPMSC, 2023) and the International Land Measurement Standard (ILMSC, 2019), is planned to be included in part 6. Part 6, ‘Implementation’ is planned to be developed in cooperation between OGC, ISO TC 211 and FIG. The project for part 6 could start in February 2026 if Part 5 is to finish in late 2025. Encoding of Part 5 elements could be done in parallel with its approval.

The development of the various parts is executed in parallel, but the revision and voting procedures take place independently. Figure 2 shows the status (September 2023) of all parts of the second edition, while the expected publication year is presented below:

- 19152-1: October 2023
- 19152-2: January 2025
- 19152-3: March 2024
- 19152-4: June 2025
- 19152-5: September 2025
- 19152-6: depends on start within OGC (Standards Working Group)

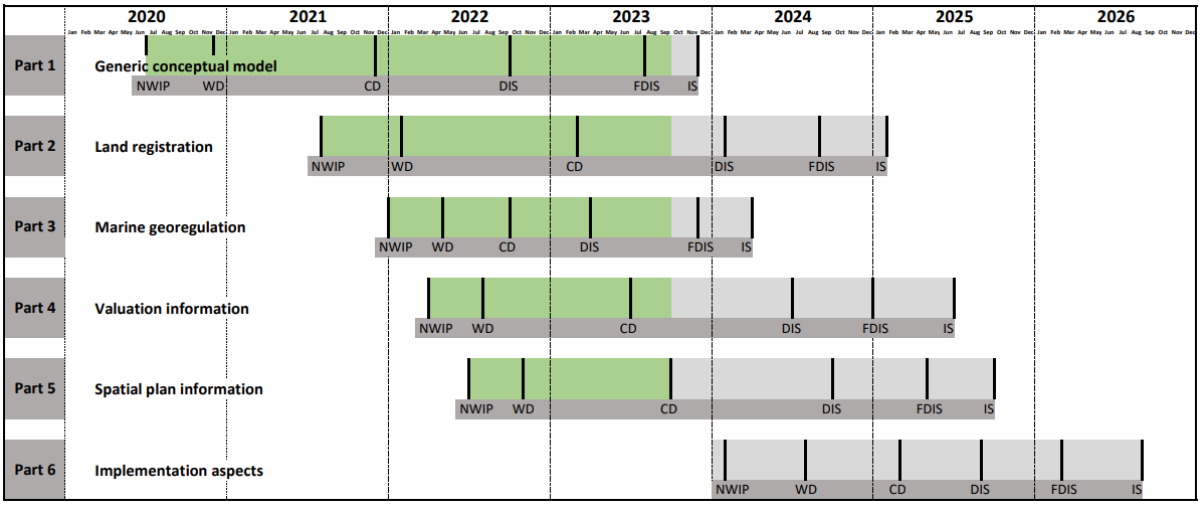


Figure 2. Planning of the development of the different parts of the second edition of LADM (NWIP = New Working Item Proposal, WD = Working Draft, CD = Committee Draft, DIS = Draft International Standard, FDIS = Final Draft International Standard, IS = International Standard). September 2023.

3. OGC WHITE PAPER ON LAND ADMINISTRATION

This chapter provides an overview and contextual background of ongoing developments. It serves as a basis for analyses and definition of requirements and needs association with data acquisition, maintenance, and dissemination of data. Requirements range from the development of 3D cadastre (including underground utilities and infrastructure) to the initial set up of a land administration or initial data collection. Initial data collection may concern creating an overview of all people to land relationships in a certain area. Data maintenance is crucial: people-to-land relationships are dynamic. Certain aspects of interoperability are explored concerning the establishment of Public Private Partnerships (PPPs). PPPs can be organized within a technical context as web services, portals and/or data exchange mechanisms.

3.1 Data collection

Comprehensive Recording of legal status:

Ongoing urbanization and development of infrastructures require a proper recording and registration of the legal status which can only be provided to a limited extent by 2D cadastral systems. 3D, including indoor modeling, is required to capture the whole legal and spatial dimension, which includes the marine environment.

Different Approaches based on land value:

In cases where value of land is higher or an intensive level of land use exists, conventional field surveys using high-precision instruments (GPS, Total Stations, Laser scans) can be deployed as usual. Areas with lower value may require other approaches (use of imagery, lidar, radar). By following the Fit-For-Purpose approach, Land Administration is simple at the start and can improve over time whenever necessary. It is a dynamic process: it is adapted to different countries/territories, applied technologies and administrative approaches. The approach must be gender sensitive, transparent, and highly participatory.

Key Role of Metadata and LADM:
Implementation of the Fit-For-Purpose Land Administration approach requires a good model for data description using metadata, as incorporated in LADM. LADM supports the continuum of land rights and a continuum of approaches in data acquisition and recordation and many different representations of spatial units (point-based, line-based, polygon-based, and volume-based), and parties (from groups to individual and non-natural persons). Different types of survey approaches must be accommodated to allow integration of new cadastral data with existing data, and to assure retention of original field observations. In all cases there should be options to include rights and right holders with attributes. Adjustments of field observations to existing cadastral spatial data is performed in the field or in cadastral GIS posteriori. Additional surveys are also used in support to quality improvement of cadastral data.

Cloud Based Data:
Modern technology, including mobile apps and cloud based platforms, streamlines field data exchange to a cloud-based GIS environment, enabling remote access and observation. Field surveys provide a comprehensive overview of all existing land relationships, including overlapping claims.

Automated Feature Extraction and Future Prospects:
Automated feature extraction may be applied to boundaries of plots bounded by topographic features. If extracted features are visualized on printed or screen-displayed imagery, they can be used to identify features that are identical to cadastral boundaries. Feature extraction may be helpful in estimating the number of parcels that can be expected in project areas. Further progress and improvements with automated feature extraction is anticipated in the years ahead.

Challenges in Data Acquisition:
Data acquisition for a vast amount of spatial units is an enormous operation. Numerous polygons, lines and points are to be surveyed (or in a central place in the village) and need to be linked to formal and informal holders of real rights and/or use rights. The organization of this process requires enormous amounts of human-supported activities related to logistics and case management – which can be linked to geographic information.

3.2 Processes, maintenance and transactions
Cadastral Map Updating and Data Management: Cadastral map updating includes adjustments and transformations of field observations (collected at different moments in time and with different survey instruments or via use of imagery from different sources) to the spatial database. Implementation of tolerances to manage the differences in measurements should be flexible and purpose related. Results of subdivisions of spatial units and the results of land readjustments and land consolidation may need to be shared with other systems.

Interconnection with Other Systems:
Management of areas is needed: there may be more than one area to be maintained for the same spatial unit and the legal and accurate area as calculated in the cadastral GIS may not match other records.

Data Layers and Quality Enhancement:
Conversion of social tenure to legal tenure is a process that may require different levels (layers) of data with related attributes. The same is valid for geometric quality improvements of the cadastral map.

Electronic Signatures and Data Provision:
Processes can be organized based on the use of electronic signatures in cases of applications and information requests requiring public or private keys and encryption/decryption.
Provision of information to data collectors for initial data collection or maintenance is a specific but very important process (task management, logistics). This provision of data can be paper-based imagery or digital. Data provisioned in participatory approaches include: roles, ids, photos, signatures, fingerprints, video, voice recording, right types, restrictions, and disputes.

VGI and Crowdsourcing for Land Administration:
VGI and crowdsourcing for Land Administration where rightsholders and communities collect and maintain their own data with a certain level of professional support for quality assurance, etc.

Integration for Comprehensive Land and Property Rights:
To ensure securing land and property rights for all, there needs to be concerted efforts to improve the production of data and the generation of information needed to record all forms of people-to-land relationships that will provide effective and efficient Land Administration Systems. There will be a need for considerably more integration across the various national data and information systems and platforms in order to leverage the most effective data and analysis for evidence-based policy formulation and decision making.

Transactions and Standardization:
Updates, changes and deletions may concern (attributes related to) parties, RRRs, basic administrative units and spatial units. Common transactions are buying and selling, establishment of (a) right(s), (e.g. encumbrance, usufruct, or tenancy) and the inclusion of the result of spatial planning, e.g., land consolidation or land readjustment. More generic process-related modules (Stubkjaer, et al., 2007) in data acquisition and data handling as well as maintenance and publication are needed. Standardization can make it easier to monitor the progress of global indicators. LADM has roles included as well a series of dates in processes – but LADM Edition I does not include yet processes for initial data acquisition, data maintenance, and data publication. Cadastral data maintenance can be 'systematic' or 'sporadic.' Transactions require source documents providing the basis for changing and updating the data in the database – from one consistent state to another. Attributes in all classes can be subject to change.

Blockchain and Smart Contracts:
The blockchain is a secure mechanism to handle and store transactions in a distributed ledger. Once a transaction has taken place, it cannot be altered or erased from existence and a transaction is irreversible. Not only the transaction itself, but also the history of transactions, is safely captured, making the data immutable and hence providing trust. Blockchain is known

as the ‘distributed ledger;’ it is the database that provides proof of who owns what at any given time and it is publicly available and publicly maintained. Smart contracts are contracts whose terms are recorded in a computer language instead of legal language. Smart contracts can be automatically executed by a computing system,

Geometric Accuracy and Quality Labels:
Geometric accuracy can be represented with quality labels identifying the relative and absolute accuracy of geometric data. This is relevant for adjustments to existing coordinates later on during maintenance and for the integration of data from different sources collected with different instruments and tools in different survey approaches. Accuracy is also about ‘linking’ polygons and people. That means the quality of the links between spatial units (in cadastre) with rights (in the registry) and rightholders (basically in population register or business register).

Required Functionalities and Data Collection:
Required functionalities should be deployable on a single device, i.e., functionalities for using image-based data acquisition combined with collection of coordinates with handheld GPS, biometric data (fingerprint identification and facial recognition), and voice/video recording in support of object identification. Devices supporting these functions could also be useful for inspections, for fieldwork related to building and construction permits, for cadastral maintenance, etc. Land data collected on many devices should deliver results in formats based on operational standards.

Legacy Data and Digital Archiving:
Legacy data may be located and stored all over a country in administrative (legal) and spatial (survey) archives. The paper documents in those archives often have a legal meaning. After digitizing the documents, they are not yet archived in a unified manner compliant with (international) standards: this applies to both the archives with the maps as well as the archives with the deeds. Having a digital archive is one of the preconditions for e-services to function optimally. Stages of digital archiving may be distinguished: protection of the existing archives; scanning and indexation; quality improvement of the archives; optimization of internal consistency; and integration of the digital archive in workflows.

3.3 Interoperability and Outputs

The development of effective land administration systems necessitates a robust structure of interoperability, data sharing, and data integration. This structure extends to external databases, including those containing information on addresses, population registers, businesses, buildings, utilities, and more. Access to these databases is crucial for bolstering the information infrastructure, with a particular focus on the following key areas:

Imagery and Remote Sensing Technologies:
The integration of libraries featuring cloud-free imagery compositions, generated on a large scale through remote sensing technologies, is indispensable. This integration includes approaches to initial data acquisition, methods for public review and inspection, and comprehensive coverage checks.

Data Sharing and Avoiding Duplication: Data sharing principles play a pivotal role, allowing data to be collected once and utilized multiple times by establishing linkages with Spatial Data Infrastructures (SDIs). This approach helps prevent redundant data collection and maintenance while ensuring that data remains 'kept at the source.'

Internet-Connected and Disconnected Environments:
Services must be adaptable to both internet-connected and disconnected environments, recognizing that internet reliability can be variable across different regions. This adaptability supports online declarations of land rights by property holders while maintaining quality assurance procedures.

Diverse Applications:
The potential applications of land administration services are multifaceted. These encompass reporting land disputes and conflicts, handling requests for information, publishing land data, delivering products and services, formalizing land rights, renovating maps, enhancing quality, and digital archiving.

Fiscal Registries:
Fiscal registries or databases serve as repositories for a comprehensive array of property unit characteristics, encompassing legal, physical, geometric, economic, and environmental aspects. These registries play a pivotal role in property valuation and taxation.

Interconnection with Public Registries:
A robust land administration infrastructure is imperative to establish linkages between fiscal registries and other public registries, including cadastres, land registries, building and addresses registries etc. This interconnection facilitates the generation of titles, certificates, spatial data, legal and administrative information, statistical data, and more.

A well-integrated and interoperable land administration system necessitates seamless access to external databases, robust data sharing mechanisms, adaptability to varied connectivity scenarios, and a wide array of applications to meet the evolving needs of land management and administration.

4. CONSIDERATIONS & ACTIONS TO ADVANCE LADM IMPLEMENTATION

This chapter provides some considerations and possible actions that could be relevant to the further development of the Land Administration Charter for a Standards Working Group at the OGC. With the ongoing developments a new OGC Standards Working Group (SWG) is planned to be formed, it is expected that OGC members propose a OGC Land Administration Domain Model LADM SWG. The SWG name, statement of purpose, scope, list of deliverables, audience, and language specified in the proposal will constitute the SWG's official charter. This charter will be prepared by OGC, but considerations and actions to advance LADM implementation are welcome and can be forwarded by DWG members.

Decision making on participation in the SWG is beyond the scope of this paper. It does, however, suggest consideration of the "digital gap." There are countries with a development edge that have the knowledge and capacity to participate. For other countries it is more difficult. Representation of those countries could be through GLTN, FIG, ELRA/CINDER. Or perhaps through some other approach. Organisation of participation/representation of countries in Africa could be an issue for discussion during the “First High-Level Forum Meeting of Presidents of Land Professional Associations in Africa” to be held in Addis Ababa in November 2023 and similar events in other continents.

Overall land administration (developing, modernizing, updating etc.) is a complex task due to the need to accommodate diverse regulatory and policy context. Interoperability between underlying technologies and systems is key in providing the necessary flexibility. There is an impetus to guide developing nations in a programmatic way to establish cost-effective, interoperable land administration, to upgrade current manual processes, and to field automated solutions that can be flexibly adapted to new data sources and new technologies.

The OGC White Paper from 2019 provides an overview of needs and requirements discussed by an inventory by an international group of experts during the LADM Workshop in Delft, The Netherlands in March 2017 and in Zagreb, Croatia in April 2018. Considered in this way, a series of requirements and proposals from the 2019 White Paper have now been developed (or are being developed) at ISO/TC211. It may be considered to discuss if a new version of the White Paper is needed, with inclusion of the Social Tenure Domain Model (ISO, 2012; FIG, 2010).

The LADM Development team is aware of approximately 50 country profiles and 10 country implementations and 17 STDM (Social Tenure Domain Model, a LADM specialization) implementations. The STDM implementations are mainly in developing countries with support of the UN-Habitat Global Land Tool Network (GLTN)). There is attention from the geospatial software and consulting industry. This interest has been discussed in the Land Administration Domain Working Group (DWG) and during various LADM Workshops.

This interest in the use of LADM drives the need to develop an encoding Standard to assist the implementing community. Currently, countries implementing LADM have to develop all the steps and technical encodings before arriving at an operational system. This is because ISO 19152 is a conceptual model, specific LADM implementation standards are missing. Since this is done by every country individually (except form STDM implementations) there are many different solutions, which is reducing the actual overall aim to support interoperability. This also increases implementation cost when adapting LADM. For industry partners (OGC members) an encoding standard would enlarge the possibility to reuse their LADM software in multiple countries (jurisdictions). All these aspects are proposed to be addressed by the proposed LADM implementation standard.

In all cases, the SWG Charter provides a basic timeline plan for their activities. The initial scope of the SWG LADM is suggested to develop:

- a methodology to develop LADM country profiles. Kalogianni (2021) introduces methodological steps for the development of country profiles, it is expected that her approach could be included in part 6;
- management/maintenance rules for semantically rich code list values (SKOS);
- a metamodel for structuring and managing semantically enriched code list values;
- a encoding Standard of the five parts of the ISO LADM Standard (currently under development). The content of the encoding Standard will derive requirements from conceptual model items in the source LADM Parts and from (a new version of) the White Paper. One or more encoding formats will be considered, referencing international Standards such as Geography Markup Language (GML), GeoJSON, Features and Geometries JSON (JSON-FG), and/or the OGC API family of standards-compliant recommendations for the development of interoperable LADM schema-based information system;
- workflows/procedures of the most important LA processes;
- instruction guidelines for property measurement, such as the International Property Measurement Standards (IPMS) and the International Land Measurement Standard (ILMS), (IPMSC, 2023; ILMSC, 2019); and:
- (optional) blockchain/ledger technology-based implementation guide. This may be in cooperation with ISO TC 307 on blockchain technologies and distributed ledger technologies.

5. CONCLUSIONS AND RECOMMENDATIONS

There is a clear challenge for the global land community and for the global geospatial community: secure land rights for all people, in all places, at all times. The biggest challenge is to keep the information on land rights up to date and accessible at the appropriate level of accuracy. In 2012, the Land Administration Domain Model (LADM) was established as an official ISO standard, a significant milestone in land administration. LADM serves as a comprehensive framework for the information-related aspects of land administration, offering a shared terminology. Importantly, it accommodates all types of land tenure and provides a robust foundation for various land administration components, including 3D Cadastre and marine spatial data.

The ongoing revision of LADM, currently underway, seeks to enhance its capabilities and address previously unmet requirements. These additions include valuation information, spatial planning data, and marine georegulation, further solidifying its relevance in the evolving land administration landscape. Additionally, it emphasizes the importance of metadata and LADM in implementing the Fit-For-Purpose Land Administration approach, which emphasizes cost-effective, transparent, and participatory data collection and management.

The overall recommendations can be summarized as follows:

- A Charter for the LADM Standards Working Group within OGC should be created to facilitate the development and implementation of LADM. This Charter should involve stakeholders from various sectors, including business, government, and academia. To ensure equitable participation, strategies should be developed to engage countries with

varying levels of development and technological capacity. Representation through organizations like GLTN, FIG, ELRA/CINDER, or other similar bodies can be explored. Emphasize on the the importance of interoperability, data sharing, and integration across land administration systems and external databases is needed. This will facilitate comprehensive land and property rights recording and support a wide range of applications, including land dispute resolution, data publication, and property valuation. A critical next step is an encoding standard for LADM to assist implementing countries and organizations. This standard should encompass methodologies for developing LADM country profiles, management rules for semantically rich code list values, and metamodels for structured code list values. It should also establish encoding formats that promote interoperability.

- The functionality and options for use of LADM should be better known and communicated. LADM is a flexible standard that can meet local requirements. It is not a prescriptive standard – it is descriptive. LADM can also be described as a land administration expert language. It describes the common denominator in land administration worldwide.
- Standards like the LADM are crucial to jump-start new initiatives and are connecting top-down and bottom-up projects. It is very important that there is awareness of this at policy level. Policies should support the implementation of standards particularly when such standards are globally agreed.
- Internationally agreed-upon and open standards will be key to unlock the value of data and the wealth of information needed to recognize all forms of people-to-land relationships, which is vital for the well-being of all humanity and sustainable development.
- It is recommended to look for options to use the OGC Innovation Initiative as one of the tools to develop LADM part 6. Business, government and academic stakeholders need to be involved.
- These recommendations reflect critical steps needed to advance the implementation of LADM and promote effective, efficient and equitable land administration practices worldwide. Collaboration among key stakeholder and ongoing reviews of these recommendations are essential to address evolving challenges and opportunities.

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Position paper 1
Urban development / plan information LADM part 5

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1. INTRODUCTION

Anthropogenic processes caused by humans (mainly buildings) are a frequent element of spatial planning and usually have the greatest influence on the landscape and the inhabitants of the territory. It is necessary to reflect and respect the past (history), truthfully portray the present (state) and examine the impact of new developments on the future (intention). This is the only way to meet the needs of the current generation without jeopardizing the conditions of future generations. The use of 3D elements for decision-making in the territory enables a view on the issue from a larger perspective or context, which 2D visualization does not offer. Spatial relationships and connections to the surroundings are essential for decision-making in the territory. With the development of 3D visualizations and applications, it is possible to convincingly model the state of the territory in various scales of detail. It is possible to visualize existing or future design elements into the given models and present the results to experts or the public as part of an online or offline solution (Rucký and Janečka, 2022).

Information about land ownership, land use policy and rights, restrictions and responsibilities (RRRs) are vital in spatial planning, particularly in densely and intensive-use of spaces, particularly in the urban area (Indrajit et al., 2020). Overlapping RRRs in space are however typical for the current built environment. As stated in Kitsakis et al. (2022), the extent and the content of the right of ownership in the various legal systems is significantly affected by legal provisions and restrictions deriving from public law (Public Law Restrictions (PLRs)). Therefore, the 3D LAS should integrate RRRs coming from both land administration and spatial planning processes. The importance of the 3D aspect in spatial plans needs more attention, to show the true size, depth and height of the planned developments in our dense (urban) environments. In addition, the temporal aspects, arranging possible developments over time, and the multi-scale/multiple levels of planning, from national and provincial to detailed zoning plans at the municipality and neighborhood level. Conceptually, the 3D spatial representations combined the temporal and scale aspects result in 5D models.

Considering interoperability between the spatial plan and land administration as a base for urban development, all aspects (legal, organizational and technical) must be explored.

2. STATE OF THE ART

The 3D spatial plan needs to be interoperable for further integration with other data, such as 3D land administration. Lack of interoperability may create unwanted information asymmetry. The international standard under development ISO 19152-5:202X Geographic Information — Land Administration Domain Model (LADM) — Part 5: Spatial plan

information is going to provide the general reference model, as a newly added part to the existing core LADM (i.e., ISO 19152-1:202X and 19152-2:202X), for all objects of spatial planning covering land/water and below/on/above surfaces. This standard supports 4D (3D + time) representation of the spatial plans including marine spatial plans. It should be considered as the first basic step to promote interoperability through integration of output spatial planning processes with land registry and cadastre.

The foundations for ISO 19152-5:202X Geographic Information — Land Administration Domain Model (LADM) — Part 5: Spatial plan information are given in Lemmen et al. (2021), Indrajit et al. (2020, 2019) and the EU's Plan4all | Open Geodata for Planning Activities initiative (Murgante et al., 2011); see https://www.plan4all.eu/: *"The idea of creating the Plan4all association arose as a result of the eContentplus project Plan4all (2009-2011). It was established during the FP7 project Plan4business (2012-2014). Plan4all was focused on large scale spatial planning data harmonisation in Europe and provided draft INSPIRE data specifications for five spatial data themes including land use and land cover."*

3. KEY CHALLENGES

- Land registry and planned land use information is today not yet integrated in most countries (van Oosterom et al., 2019). Before 19152-5, these domains were not based on the same conceptual model and it was not possible to be easily used together. The extensible basis for the development of efficient LAS based on a Model Driven Architecture (MDA) and covering the common aspects shared by objects created by spatial plans should be developed.
- Various differences in concepts and vocabulary/terminology for land registry and spatial planning are the practice today. The shared vocabulary is needed.
- Digital representations of physical public utilities and underground infrastructure registration are not a part of the land registry. In some countries (e.g. The Netherlands), the corresponding legal spaces for these utilities are in the land register together with the associated RRRs and parties. As Dželalija and Roić (2023) mention, with rising urbanization, more complex buildings and infrastructure, underground and overground construction, as well as a limited amount of space in such areas, the proper registration of utilities has become more important than ever.
- One of the challenges is how to model the Public Law Restrictions (PLRs), many of them are arising from spatial plans (in LADM part 5), but not all types of PLRs are from spatial plans (in LADM part 2). One could also argue that the plan area's should also be explicitly registered as RRRs (in LADM part 2). Good guidelines are needed here.
- There are huge gaps between the (information) systems used in the land registries and by the spatial planning authorities. This makes it costly to arrive at a minimal level of interoperability to enable the data exchange needed between the two systems. Even worse is the data in the different systems are now properly aligned there will be issues with data inconsistencies (or mistakes).

- There are quite diverse communities of professionals behind the LR and SP systems and processes. They are not talking to each other, and they do not really understand each other, due to their different professional backgrounds and education. This is true both at international level and also in most countries.
- Guaranteed (in terms of source, update and validity of geometries) open 3D data for urban development:
    - 3D legal spaces (3D cadastre / 3D LAS).
    - 3D spatial plans - converting 2D planning objects into 3D planning objects (e.g. maximum allowed building heights).
    - 3D "as built" physical spaces / topography (City Information Modelling (CIM) / GeoCIM and also non-city areas).
    - Building Information Modelling (BIM) - in some countries (e.g. Czechia) seems to be the driving force behind the developments of 3D data.

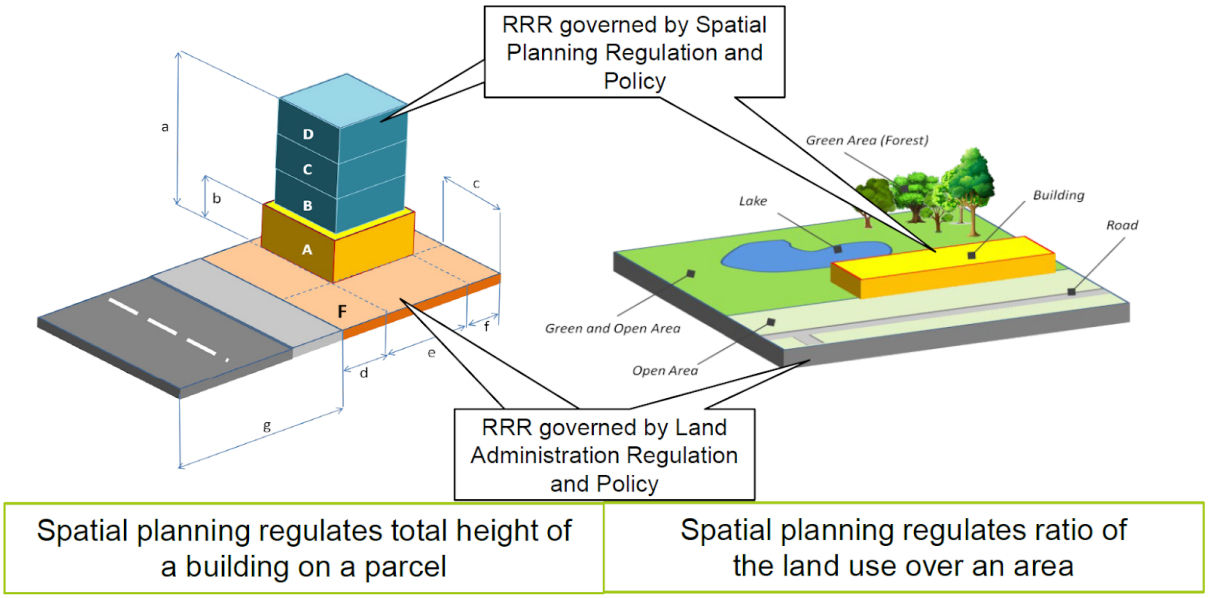
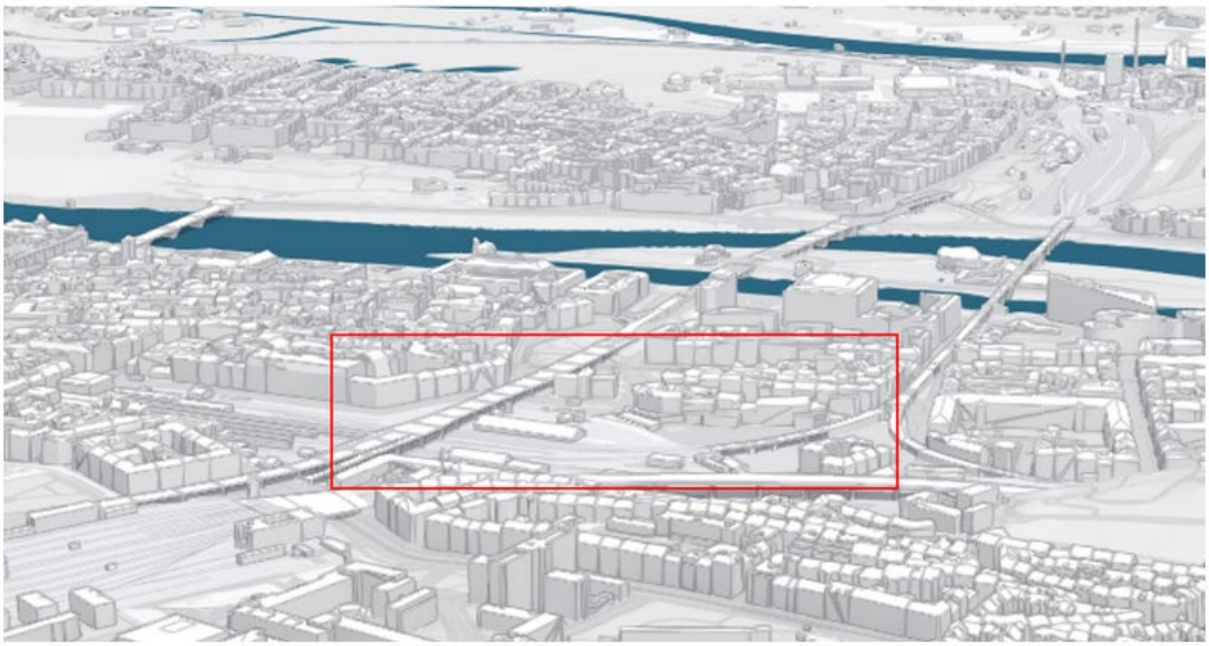


Figure 1. Spatial planning information as part of complete land administration (van Oosterom et al., 2019).

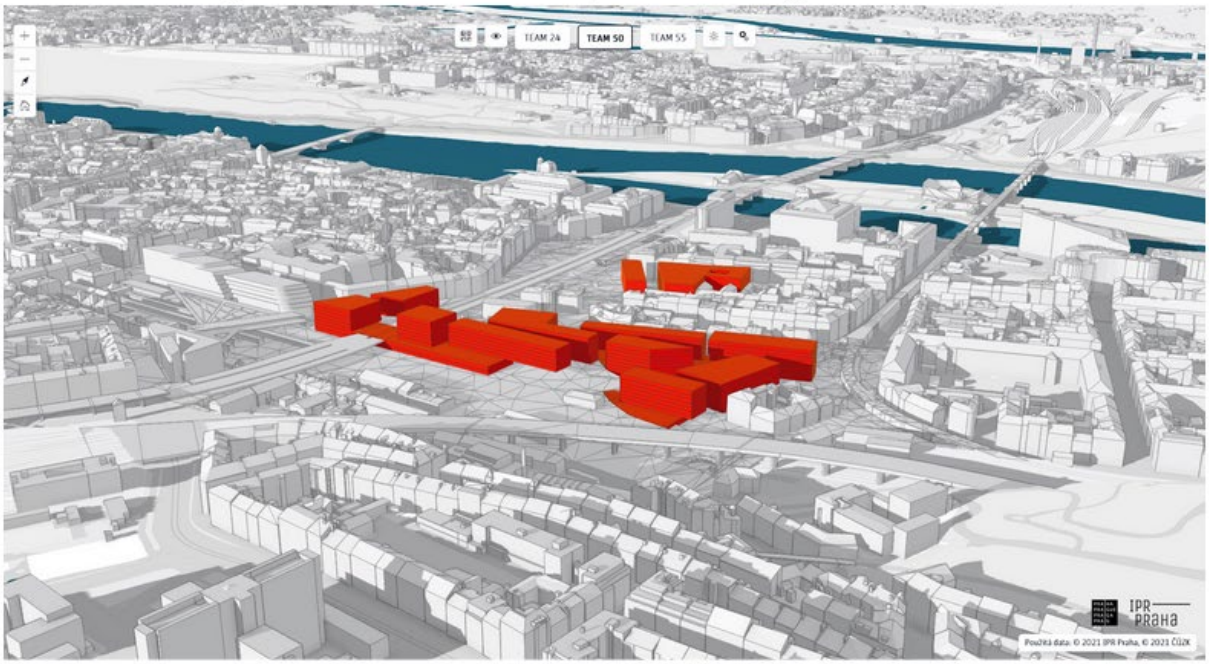
4. POSSIBLE SOLUTIONS

- International standardization. Spatial planning information should be a part of complete land administration (Figure 1).
    - ISO 19152-5:202X enables the combining of land-use planning and development in land administration information from different sources.
    - ISO 19152-5:202X also provides the terminology for spatial plan information as part of the land administration.

- Explore, design and evaluate an integrated land registry and spatial plan information model in one or more countries, i.e. a LADM LR/SP country profile, where these different functions of land administration are traditionally already quite well organized in harmonized workflows, possible within a single organization (e.g. Israel, Malaysia…)
- Perform a cost-benefit analysis in one or more countries comparing the current separate LR/SP systems with an integrated LR/SP system approach. Aspects to be considered: cost of current ad hoc conversions, cost due to mistakes/data inconsistencies, cost of developing integrated system
- The reasonable use cases demonstrating the feasibility and usefulness of such approach, e.g.:
    - Processing panoramic sketches of the plan of the future building complexes (Figure 2). First, the information about the parcels where the new buildings should be built is needed. Next, for example, the maximum height of intended constructions/buildings must meet the height limits given by the spatial plan. Finally, new buildings must not affect historical panoramas.
    - Automatic building permit issuing. To get the building permission, the necessary checks, e.g. checking building designs against building regulations laid down in spatial plans, must be done (a nice example here is the automated permit checking system as recently being in use by Estonia).
    - … and others.
- Utilities and underground infrastructure as part of 3D cadastre /3D LAS, i.e. utilities and underground infrastructure as property.
- Organize joint sessions or even workshops with both the LR and SP communities; e.g. within the FIG Working Weeks (or Conferences) have commissions 7 and 8 tasked with the challenge to enable, stimulate such a joint session or event. Also, the traditional LADM/LR community could/should try to be more involved in SP communities; e.g. PLPR, Plan4all with the recently started follow-up project PLUS Change (Planning Land Use Strategies: Meeting biodiversity, climate and social objectives in a changing world).



(a) The 3D digital model of Prague (IPR, 2023). The intended future building complex should be placed in the area marked by the red rectangle.



(b) The portrayal of the future buildings within the 3D digital model of Prague (ARCDATA, 2022).

Figure 2. Processing panoramic sketches and views of planned building complexes.

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Position paper 2
3D legal building models/BIM

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Key words: 3D cadastre, 3D legal building models, BIM.

1. INTRODUCTION

This paper serves as the basis for discussions on the working session 3D legal building models/BIM, being one of the four working sessions at the 11th International FIG Workshop on LADM/3D Land Administration. The paper is intended to initiate discussions on the 3D legal building models/BIM and aims at identifying the main topics concerning the 3D legal building models/BIM and further future research.

The development, evolution and modernization of Land Administration Systems around the world vary a lot, as they depend on national legislation, regulation, institutional arrangements and system's technological maturity (Kalogianni et al. 2020).

The paper starts by presenting State of the art in the domain of Building Information Modeling (BIM). It continues by presenting some key issues and the challenges related to research in this field. Possible ways for address the challenges and enhance the implementation of 3D legal building models and Building Information Modeling (BIM). The paper ends with conclusion.

2. STATE OF THE ART

Building Information Modeling (BIM), also called n-D Modeling or Virtual Prototyping Technology, is a revolutionary development that is quickly reshaping the Architecture-Engineering-Construction (AEC) industry. BIM is both a technology and a process.

The information obtained from BIM about the facility floor areas, rooms, zones, systems, and component types and attributes is how a facility is operated and maintained. BIM proves valuable in this process as it provides a comprehensive understanding of facility components and systems (Matarneh et al. 2022).

Today, there is a trend to directly design buildings in 3D. Within the spatial development lifecycle thinking, this design will be reused via BIM / Industry Foundation Class (IFC) encodings in the subsequent phases, such as, obtaining permits, financing, constructing, etc. IFC files as actually submitted to responsible authorities for building requests could be used and if needed, to be upgraded to be used for 3D Land Administration purposes.Next step can be developing a database based on LADM to store the country profile and a 3D web prototype to visualize and query the model (Alattas et al. 2021).

A 3D legal building model refers to a three-dimensional digital representation of a building that is created in accordance with legal and regulatory requirements. It is commonly used in urban planning, architectural design, construction projects, and related fields.

The primary purpose of a 3D legal building model is to provide an accurate and comprehensive visualization of a building's structure, design, layout, and features while taking into account the legal constraints and guidelines that govern the construction process. This type of model is particularly valuable for facilitating communication and collaboration among various stakeholders involved in a construction project, including architects, urban planners, engineers, surveyors, developers, authorities, and the general public.

Key features of a 3D legal building model include:

- Accurate Representation: The model accurately depicts the dimensions, proportions, and design details of the building, ensuring that it reflects the intended real-world appearance.
- Legal Compliance: The model is designed in line with all relevant legal and regulatory requirements, such as height restrictions, setbacks, land use regulations, fire safety codes, and accessibility standards.
- Visual Context: The model provides a visual context for understanding how the building will fit into its surrounding environment, considering neighboring structures, open spaces, roadways, and other factors.
- Design Assessment: Stakeholders can use the model to assess the building's design, functionality, and potential impact on the local community and infrastructure.
- Permitting and Approvals: The model can be submitted as part of the permit application process to demonstrate compliance with legal standards, helping authorities review and approve the project.
- Public Engagement: The model facilitates public engagement by enabling citizens and community members to visualize and understand proposed changes to their environment.

3. KEY CHALLENGES

- Most of the Land administration systems around the world are using 2D floor plans to define the legal boundaries, therefore, what can motivate the government’s stakeholders to use 3D models instead of the 2D floor plans?
- There are two types of 3D models that can be used for defining the legal boundaries of properties, As built and 3D models during the design phase. Which of these 3D model types should be used?
- There are many difficulties and challenges facing the research groups to test real world buildings in the field of land administration when the research groups are requesting 3D models and 2D models from the government’s stakeholders. What are the reasons behind these challenges? and how can the research groups build better communication with the government’s stakeholders?

- Privacy issues are considered one of the justifications that are used by the government's stakeholders to refuse the requests of the research groups to obtain the requested information. Therefore, what are the privacy issues? And privacy issues are considered the most problematic when it comes to the domain of research?
- There are many types of buildings in our cities, such as residential, apartments, studios, villas, towers etc., and there are different terminologies used around the world to represents these types of buildings and their indoor spaces. Do we need to define a list of terms to be used to harmonize these terms?
- Many local authorities use 2D floor plans during the implementation of the local regulations related to defining the legal boundaries of properties. Therefore, would the 3D model provide better understanding of the legal boundaries? And how can the research communities change the opinions of local authorities to accept the idea of using 3D models as one of the requirements to define the 3D legal boundaries?
- Architecture companies are using different 3D formats to build the 3D models, and these 3D formats can create many issues during the conversion from one to another and during the exchanging of the 3D models between research groups, and between Architecture firms and the local authorities to define the legal boundaries or to extract the legal boundaries from the 3D models. What is the optimal format of 3D model that should be used to reduce these kinds of issues?
- Semantic information is very important to understand and to define the legal boundaries of the building' legal spaces, however, is there a minimum level of the semantics information that should be included in the 3D models? What is the information that should be included to build a 3D model that can be used anywhere around the world without any issues during defining the legal boundaries?

4. POSSIBLE SOLUTIONS

In order to address the challenges and enhance the implementation of 3D legal building models and Building Information Modeling (BIM), several potential solutions can be considered:

Standardized Data Format Developing and adopting standardized data formats for 3D models, such as the Industry Foundation Class (IFC), can mitigate interoperability issues. Establishing a universal format would facilitate smoother exchange of models between different software platforms, reducing data loss and compatibility problems.

Semantic Enrichment Ensuring that 3D models include a minimum level of semantic information is crucial for accurately defining legal boundaries. Implementing standardized semantic definitions and classifications would enable a clear understanding of building legal spaces, aiding both professionals and authorities in the assessment and interpretation of regulations.

Government Collaboration Collaborative efforts between government sectors responsible for urban planning, construction permits, and data management are essential. Developing streamlined processes for obtaining 3D models or 2D design floors from responsible

government bodies can expedite the integration of accurate data into land administration systems.

Public Engagement Platforms Creating accessible platforms that allow the public to interact with 3D legal building models can enhance community engagement and understanding. Public input can contribute to informed decision-making and foster a sense of ownership in urban development projects.

Educational Initiatives Initiating educational programs and training for professionals and stakeholders involved in the construction and land administration sectors can promote a better understanding of 3D models and BIM technologies. Increased awareness can lead to more effective utilization of these tools.

5. CONCLUSION

The emergence of 3D legal building models and Building Information Modeling (BIM) represents a transformative development in the Architecture-Engineering-Construction (AEC) industry. These technologies offer accurate representations of building designs while adhering to legal constraints, promoting collaboration among stakeholders, and streamlining urban development processes. However, challenges such as interoperability, privacy concerns, types of 3D model and semantic clarity need to be addressed for the widespread adoption of these technologies. By standardizing data formats, enriching semantic information, fostering government collaboration, ensuring privacy, and promoting public engagement, the potential benefits of 3D legal building models and BIM can be fully realized. As technology continues to advance and urban environments evolve, the integration of 3D legal building models and BIM into land administration systems holds the promise of more efficient, transparent, and inclusive urban planning and development.

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Position paper 3
Legal aspects of 3D Land administration

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1. INTRODUCTION

This position paper serves as the basis for discussions at the working session theme Legal aspects of 3D LA, being one of the four working session themes at the 11th International FIG Workshop on LADM (Land Administration Domain Model) /3D Land Administration), in Gävle, Sweden, 11th-13th October 2023.

The intention of the paper is to initiate discussions on the legal framework of 3D land administration, including 3D cadastre and the use of the Land Administration Domain Model (ISO, 2012), and aims at identifying main topics concerning the legal aspects and further future research.

The paper starts by presenting and relating to results from the earlier FIG workshops on land administration and 3D Cadastres and related research on legal issues in order to describe the state-of-the-art in the research field(s). However, what can be considered as legal aspects? In this paper we use the definition provided in Paulsson and Paasch (2013), dividing 3D cadastre research into four categories: Legal, Technical, Registration and Organisational. The legal category is defined to contain "[...]publications on topics such as real property rights, restrictions, responsibilities, real property, superficies solo credit, security of tenure, legislation, subdivision, spatial planning, legal objects and the legal framework." The category is in other words rather wide and allows for a multitude of related legal subjects to be discussed and researched. This can also be noticed by the spectrum of publications addressing a spread of sub themes in legal research on 3D land administration and cadastre. Examples are the FIG 3D cadastre and 3D land administration workshops as well as input from e.g. publications at the FIG working weeks, also addressing legal issues on 3D land administration. They can be classified into different sub themes, such as BIM, 4D cadastre, Marine and water applications, valuation, LADM and other standardisation. Those topics are however also found in the other categories and it depends on the focus of the individual research how a publication should be classified.

The input to the working session is the flow of peer reviewed papers as well as abstract reviewed conference papers on 3D real property research during the last two decades. The purpose of this paper is to in short present a state of the art of the topic legal aspects of land administration, along with key challenges and ideas related to possible solutions to these challenges. The paper continues by presenting some key challenges related to research in this field. Possible ways for how legal research can be increased are presented by providing examples of possible research issues. The concluding part of this paper, finally, presents a possible way forward.

2. STATE OF THE ART

There seems to be an increased interest in a number of different themes of 3D land administration, especially in the context of 3D cadastre, judging from the analysis presented in e.g. Paulsson and Paasch (2013), and Paasch and Paulsson (2023). There has been a relatively constant number of publications annually during the last two decades, but it can also be noticed that the legal topic is one of the lesser researched topics among the above mentioned main categories, counting for example for only 18 % of the publications during 2001 to 2011 (Paulsson and Paasch, 2013) and 15 % of the publications during 2012 to 2021 (Paasch and Paulsson, 2023).

The legal theme is rather small numerically in relation to the technical and registration categories, but a closer inspection shows that legal research focuses on a multitude of subtopics as mentioned in the previous section. Adding topics published in recent years, e.g. in the proceedings of the international FIG Workshop on 3D Cadastres in New York 2021, we find publications on e.g. modelling of 3D underground legal spaces in 3D land administration systems (Ramlakhan, Kalogianni and van Oosterom, 2021), the linking of planning regulations for 3D zoning with 3D cadastre (Emamgholian, Pouliot and Shojaei, 2021), the organisation of rights and responsibilities in complex 3D real property developments (Madsen, Paasch and Sørensen, 2021) and the design and development of a BIM-based 3D property formation process (Sun et al., 2021).

3. KEY CHALLENGES

There are several key challenges concerning legal aspects of 3D cadastre. The legal framework(s) adopted in many countries is frequently to some extent supported by 3D visualisation of 3D objects in cadastral maps. This is often done in a very rudimental way, sometimes supported by simplified textual description of the extension of RRRs (rights, restrictions and responsibilities) in the formal legal documents / dossiers created during the real property formation process. In some cases, a 3D PDF has been registered in the national land register, for example in the Netherlands (Stoter et al., 2017).

Legal issues are connected to other issues such as technical, registration and organisational issues. The world we live in is three-dimensional, but land administration information has traditionally been treated as two-dimensional. We could, in other words, see it as a paradigm shift from the use of information in two dimensions to three dimensions. The position paper for the 3D cadastre workshop in Dubai 9 years ago (Paasch and Paulsson, 2014, appendix) pointed at 5 questions which were considered relevant to discuss. These questions form the basis for questions no 1-5 in the list of key challenges below. They are relevant also today even if much has been achieved since then, e.g. the registration of 3D legal boundaries of RRRs as 3D PDF (Stoter et al., 2017). Other issues, such as the increased focus on Building Information Modelling and how to implement a 3D land administrations system being in focus in later years, are added to the list of challenges below, see no 7-10.

1. Which types of 3D cadastral objects (3D properties) can be registered? Are these always related to constructions (buildings, pipelines, tunnels, etc.) or could they be any part of the 3D space (both airspace or in the subsurface)?
2. In case of infrastructure objects crossing 2D parcel boundaries, such as long tunnels, and pipelines and cable networks: should these be divided based on the surface parcels or treated as one cadastral object?
3. How to deal with the fact that the legal status of such an object does not have to be the same for all the ground parcels? E.g. a construction located on three real properties on the basis of different types of rights (e.g. easement, restrictive covenant, lease).
4. For the representation (and initial registration) of a 3D cadastral object, is the legal space specified by its own coordinates in a shared reference system (as is the practice for 2D in most countries) or is it specified by reference to existing topographic objects/boundaries?
5. Should the 3D registration and visualisation reflect the actual dimensions? Or is it sufficient to have a visualisation of property units in buildings based on standard floor-to floor heights? What is the legal value of these boundaries? Is an investigation of the source documents (title deed, survey plan) needed to get legal binding information?
6. How are the (national) land administration / property formation digital processes adapted to facilitate effective formation, registration, visualisation and archiving of 3D land administration objects?
7. What is the need for improved visualisation of 3D land information in a nation's real property register?
8. Are there any obstacles within the current legislation to change a nation's real property administrative systems from being based on 2D information to 3D?
9. How can real life implementation of legal aspects research results be achieved to further 3D land administration management?
10. How is the legal digital information to be archived for future use?

4. POSSIBLE SOLUTIONS

Initial ideas to be addressed at the workshop will focus on the key challenges no 1-10 listed above. The LADM is now discussed in the 3D research community and can be used as a tool as well as input, which this conference also indicates by being a joint LADM and 3D land administration workshop. LADM and other standards can be used as an input to further the discussions concerning the future development and implementation of 3D solutions in land administration, for example how to describe the legal boundaries and volumes in the national registration systems.

The results of the most recent questionnaire on 3D land administration from the FIG Working Group 3D Land Administration 2022 will be useful to study in order to understand what is the current situation on the legal aspects, how far each participating country has come in its development of 3D land administration and what issues and challenges that are mentioned in the reflection part of the questionnaire.

Collaboration between researchers from different countries and comparative studies of the different national solutions would provide insights in how a legal framework can be constructed in various ways and a possibility to learn from each other. National studies are of course also needed, and if presented in the national language, the results should preferably also be presented in English for the international audience. The working session on legal aspects of 3D land administration at this current workshop will also hopefully bring forward some useful suggestions for possible ways forward.

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BIOGRAPHICAL NOTES

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Position paper 4
Valuation Information / LADM Part 4

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1. INTRODUCTION

This paper serves as a discussion basis for a working session on '*Valuation Information / LADM Part 4*', held as one of the four working sessions at the 11th International FIG Land Administration Domain Model (LADM) / 3D Land Administration Workshop. The paper is intended to stimulate discussion on valuation information in the context of land administration and aims to identify the main issues relating to land valuation, in addition to LADM Part 4 – Valuation information as well as further research for the future.

The paper begins with a brief overview of the scope of the value function of LA, the extension of valuation information to LADM, and the current research on valuation presented at the LADM and 3D Cadastres workshops, as well as the themes of recent research. The main challenges for research are presented in Section 3. Possible solutions for increasing research on valuation are explored in Section 4, which would be helped with collaboration with researchers with a background in economics and/or statistics.

2. STATE OF THE ART

Land administration (LA) covers a wide range of systems and processes, and one of the functions of land administration relates to the value of land and its improvements. The scope of the land value function is specified as "*managing the assessment of the value of land and property, the collection of revenue through taxation, and the management and adjudication of disputes relating to land valuation and taxation*" (Enemark et al., 2005; Enemark, 2006).

2.1 Valuation in FIG Commission 7 Workshops

By the end of 2022, seven FIG Workshops on 3D Cadastres, ten FIG Workshops on the Land Administration Domain Model and one joint workshop (9th FIG Workshop on the Land Administration Domain Model / 3D Land Administration) have been organized, and none of them included a specific technical session on the value function of LA, as there were never enough accepted papers to form a session. On the topic of valuation, four papers were presented in the 3D Cadastres workshops (Tomić et al., 2012; Isikdag et al., 2014a; Kara et al., 2018a; 2021a), six papers in the LADM workshops (Kara et al., 2018b; 2018c; Tomić et al., 2018; Radulović et al., 2022; Šiško et al., 2022; Kara et al., 2022), and one in the joint workshop (Kavanagh et al., 2021). This result may not be surprising as (a) these workshops were organized by the working group of FIG Commissions 7 and 3, not Commission 9. It should be noted that there are numerous valuation papers in the FIG Congress as well as Commission 9 workshops, (b) LADM Edition I focuses on the land tenure function of LA, not

on value. While the papers presented in the 7th FIG Workshop on LADM are related to the implementation of the valuation extension of LADM (Kara et al., 2018b; 2018c; Tomić et al., 2018); in the 10th FIG Workshop on LADM one paper is about the use of mass property valuation in spatial planning (Šiško et al., 2022), one paper is mainly about the development of a country profile of the LADM valuation information extension, and the last one is related to the visualisation and dissemination of valuation units and related information. The only working session on valuation information was organized in the 7th FIG Workshop on LADM, 'Working Group 1 - LADM Valuation Information Model Extension', for supporting the development of valuation information part extension of LADM Edition II (The outcomes of the workshop and their treatment in Part 4 are listed below).

2.2 LADM Edition II and Valuation

A meeting of the UN-GGIM Expert Group on Land Administration and Management was held on 14-15 March 2017 in Delft, the Netherlands, and one of the main conclusions was to extend the scope of the LADM conceptual model to include valuation information (Lemmen et al., 2018; UN-GGIM, 2019). In turn, an extension of LADM to valuation information has already been proposed to guide the development of local and national databases and for the private sector to develop information technology products (OGC, 2019). The extension aims to cover all stages of administrative property valuation, namely identifying and grouping properties, valuing properties by individual or mass valuation, recording transaction prices, presenting sales statistics, and dealing with appeals (Çağdaş et al., 2016; Kara et al., 2018; 2020; 2021b). The extension has been developed by reusing as much as possible the existing standards and specifications that are in some way related to land valuation (see Kara et al., 2018). It is worth noting that the content of the proposed valuation information extension of LADM and the content of the land value function defined by Enemark (2005; 2006) are quite similar to each other, but the scope of the extension may be somewhat larger as it aims to cover all administrative valuations (not just taxation) and all input and output data within the valuation processes.

At the 48th plenary week of ISO/TC 211 in Maribor, Slovenia, it was decided that LADM Edition II will be a multipart standard, with Part 4 on valuation information. The New Work Item Proposal (NWIP) and the Committee Draft (CD) for Part 4 received a positive vote with some comments and observations from the member states of ISO/TC 211[1]. It is planned that Draft International Standard (DIS) for part 4 will be submitted in September 2023. The editors expect that Part 4 will be published as an International Standard (IS) in the second half of 2024. The latest version of the Part 4 UML diagrams can be found in the Harmonized Model Maintenance Group (HMMG) repository[2].

The session of 'Working Group 1 - LADM Valuation Information Model Extension' of the 7th FIG Workshop on LADM, the following points were raised by the participants in relation to the development of the LADM valuation information extension[3]. The text in [...] after each point raised explains how it has been dealt with in Part 4.

[1] https://www.iso.org/standard/81266.html?browse=tc
[2] https://github.com/ISO-TC211/HMMG
[3] https://wiki.tudelft.nl/pub/Research/ISO19152/LADM2018Workshop/pres_22a.pdf

1) There is an obvious need for a valuation information model. How should the model be designed: (a) a separate model as LADM, (b) a package to LADM (as a separate model but associated to the core LADM classes), (c) integration of the valuation model into LADM [the decision of participating members of ISO/TC 211 was option b].
2) What valuation purposes should be considered when designing (improving) the valuation information model? Tax, mortgage, transaction (sales), utilities, insurance, social transfers [The latest version of the model is designed to support all administrative valuations].
3) Land use planning should be considered when developing (improving) the model [The class level associations are created between Part 4 – Valuation information and Part 5 – Spatial plan information].
4) High rise buildings can limit the view of properties. 3D data should be used for viewshed analysis, solar potential, etc. for increasing accuracy of valuation [An informative annex – Annex B - 3D Profiles for spatial analysis – is included in Part 4 to show how 3D data can be used in valuation processes].
5) Data quality should be considered when developing (improving) the model, e.g., up-to-date data collection, data quality, metadata, etc. [QualityElement from ISO 19157 is included by all classes of Part 4, as they are all designed to be subclasses of VersionedObject].
6) The semantics of the data should be clearly defined in the model. For example, distance to amenities, distance to schools, distance to points of interest (e.g., city center, metro station, schools, business center and so on), area and volume of properties [All the data mentioned are included in appropriate classes].
7) Methods for data collection should be defined, such as LIDAR, satellite imagery, field survey, etc. [Data collection methods defined in Part 2 are utilized in Part 4].
8) Fit for purpose valuation concept may be introduced since it is not clear how many property attributes are enough for valuation? And which property attributes? (Are location, age and condition of property enough?) [An informative annex – Annex D - International valuation standards and LADM – is included to present how Part 4 and valuation standards are related. The terms and definitions used in the model derived from valuation and geographic data standards. Many attributes in Part 4 are optional in order to develop a generic model. Countries can develop their country profiles to include a country-specific needs].
9) What types of property should be included in the valuation model? For example, should the model include data on industrial properties, petrol stations, hotels? [Part 4 does not include specific data on the mentioned properties but can be extended to support these properties].
10) Production value is a new area of attention and should be considered [The inclusion of production value is left to country profiles].
11) Inclusion of unregistered lands in land registry? [This links to a Part 2 issue. Valuation information related to unregistered land can be managed through the country profiles of Part 4. The Social Tenure Domain Model, a specialisation of LADM, can also be extended to include valuation information taking the 'Valuation Of Unregistered Land: A Practice Manual' (GLTN/UN-HABITAT/FIG/RICS, 2021) into account].

12) Valuation of RRRs should be considered, such as usufruct right, ownership right, etc. [Part 4 supports valuation of RRRs].
13) International valuation standards change every two years. Is it right to use these standards to develop a valuation information model? [International standards are maximally reused when developing Part 4].
14) The model should be assessed with further use cases, such as mass valuation, 3D data, etc. More valuation country profiles should be developed for assessing the model and modelling the country specific valuation practices [See below for the country profiles of Part 4].

Several utilizations of LADM valuation information package can be found in the literature. Chinese researchers have developed a LADM valuation information country profile for the management of rural land valuation and taxation information, and for the promotion of linkage between the land registration and land taxation systems (Xu et al., 2016). Croatian researchers have used LADM valuation information to investigate the possibility of using existing authoritative land and other public registries data as a basis for mass property valuation, and to propose a profile (Tomić et al., 2021). Mongolian researchers have developed a profile as a first step towards establishing an advanced land/property valuation system in Mongolia (Buuveibaatar et al., 2023). Montenegrin researchers have developed a profile for valuations carried out for the purposes of property and tourist taxation (Radulović et al., 2023). Moreover, Turkish (Kara et al., 2019) and the Netherlands (Kara et al., 2019) country profiles are also developed to represent current situation on valuation information.

2.3 A Brief Literature Review on Valuation

In addition to the studies related to the extension of LADM valuation information, several guiding references and papers related to the value function of LA have been published in recent years. The guiding references and their brief content are as follows: The Land Administration Guidelines of United Nations Economic Commission for Europe (UNECE) includes a section examining the value of land, methods whereby value can be determined, and the nature of land and property markets (UNECE, 1996). The voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests in the Context of National Food Security (VGGT) of the Food and Agriculture Organization of the United Nations (FAO) provides a set of recommendations for the governance of the administration of the value function (FAO, 2022). Valuing land tenure rights of FAO includes a technical guide on valuing land tenure rights in line with VGGT (FAO, 2017). The Valuation of Unregistered Land of the Global Land Tool Network (GLTN) presents a practical approach for the valuation of unregistered land (GLTN/UN-HABITAT/FIG/RICS, 2021). It is also worth mentioning that the Fit-for-purpose land administration guiding principles of GLTN also includes some recommendations for supporting developing countries in designing their specific strategy for implementing fit-for-purpose LA. (GLTN/UN-HABITAT/Kadaster, 2016). Lastly, it is stated in the New Urban Agenda that developing and using basic land inventory information, such as cadastral, valuation, and land and housing price records are needed to assess changes in values (cf. Clause 104). It also noted the need for the use of geospatial information systems to share and exchange information, including the standardization and dissemination of timely and reliable data including value (cf. Clause 156, 157, and 159) (UN, 2016).

Besides the above, several papers can be considered within the context of the value function of LA. Paasch and Paulsson (2023) examined trends in 3D cadastre research between 2012 and 2021. They analyzed 530 publications on 3D cadastre and identified only eight publications (Tomić et al., 2012; Isikdag et al., 2014a; 2014b; 2015; Toppen, 2016; Kara et al., 2018a; 2020; Asiama and Voss, 2020) related to valuation topics, which is the least among identified other topics (i.e., BIM, 4D cadastre, marine and water applications). Paasch and Paulsson (2023) noted that the articles identified were mainly related to the use of 3D cadastral data in valuation processes. They explained the lack of attention to valuation in the context of 3D cadastre by suggesting that valuation issues may be more discussed in other research communities than in the 3D cadastral domain. It is worth mentioning here that the 3D cadastral questionnaire, which has been organized every four years since 2010, does not include a question on the value function.

There are many studies in broader literature that examine the use of 3D data (e.g., BIM and city models) in valuation processes, such as El Yamani et al. (2021) and Ying et al. (2022). In addition, researchers are also showing an interest in the acquisition of data through remote sensing in support of fair valuation and taxation (Koeva et al., 2021). More recently, AI/ML and computer vision algorithms and techniques are also being used to collect and fuse data to support valuation processes, as in Bin et al. (2020). AI/ML has also been used in value estimation as done in Demetriou (2017), Čeh et al. (2018), Yilmazer and Kocaman (2020) and many others. The value function of LA has been used to support LA processes such as responsible land consolidation as in Asiama et al. (2018). Last but not least, the inclusion of the impact of climate change, greenhouse gas emissions and energy performance in the valuation (which can be referred to as sustainable value) is explored among others in Bourguignon (2023).

Given the brief overview presented above, the main research themes and trends in the value function of LA can be grouped into the following categories:

1) Purposes of valuation (e.g., taxation, land consolidation, planning, regeneration, expropriation, insurance, transactions, etc.)
2) Standards related to valuation (procedural standards (e.g., IVSC, IAAO, RICS, etc.), data standards (e.g., LADM Valuation information), property measurement standards (e.g., IPMSC), reporting standards (IFRS, IVS)
3) Procedures and processes of valuation (every purpose may require different steps and data)
4) Definition and use of value types (market value, tax value, highest and best use value, strategic value, sustainability value, etc.)
5) Valuation of RRRs
6) Relationships between valuation unit, basic administrative unit (spatial unit) and plan unit (including planning restrictions that may dramatically affect value)
7) Content of a valuation registry
8) Valuation registry relationships with other public registries (e.g., building, address, cadastre and land registry, land use, taxation, transaction prices, etc.)

9) Data collection (deriving) though various methods (e.g., AI, computer vision, remote sensing, field survey, etc.) and usage of 3D data in valuation processes (data sources: 3D cadastre, BIM, city models, etc.)
    a. supporting mathematical models with variables generated by 3D analyses (e.g., view, insolation, noise, shadow) in order to better estimate/explain the values of properties,
    b. visualizing valuation units in 3D and disseminating the values of properties associated with the visualized units
10) Data quality (how to increase data quality to better estimate value)
11) Valuation approaches (sales comparison, cost, income, etc.)
12) Mass valuation, computer assisted (automated) valuation model (CAMA)
13) AI/ML algorithms and techniques to better estimate value
14) 3D visualization of valuation units and dissemination of valuation information
15) Governance of valuation information (local, central, state, professional association, etc.).

3. KEY CHALLENGES

The brief overview presented in the previous section shows that there is not a great deal of researcher interest in the value function of LA in the LA domain. The following questions on the key issues and challenges of land valuation are not intended to limit the scope of the session, but to provide an outline to start the discussion:

1) To what extent should LA professionals be involved in/ contribute to land valuation processes? Data collection, data management, data quality check, visualization and dissemination of data developing mass valuation model, price prediction model, comparing AI algorithms in price prediction, etc.
2) The main data used in the valuation process are transaction prices. However, price data are mostly not publicly available or reliable (reported value is well below the sales price). Valuation reports are often not made publicly available. Can this situation be seen as an obstacle to effective research?
3) Mathematical valuation models, formulas, algorithms (value prediction models) are generally not available to the general public. They appear to be confidential business information (formulae). Does this situation create an obstacle to checking/improving the result and doing research? If so, how is this overcome?
4) What strategies can be followed to effectively link valuation registry to the other public registries/databases such as spatial plan, PLRs, building, permit etc.? How can data from other registers be effectively used/included in valuation processes?
5) If basic registration unit and basic valuation units are different, then what sources can be used to develop 3D valuation unit visualizations?
6) Is it realistic to use 3D data in the near future for administrative valuations, such as annual property tax valuations, which may require municipal level 3D data?
7) Are valuation professionals aware of the technological developments in 3D LA? If so, are they able to use the technology? If not, are LA professionals responsible for

bridging the gap? What steps should be taken to initiate collaboration between the valuation and LA communities?

8) What should be the governance structure for the valuation information? Is there a need for a central governance body to carry out the valuation, data collection, quality control, etc.? To what extent should local governments (municipalities) be involved in valuation processes?
9) Could an international effort to document and conceptualize valuation processes (e.g., mass valuation, valuations for annual taxation, etc.) in different countries contribute to the improvement of valuation processes? Does such an effort contribute to some LA processes? Is it possible to take advantage of the International Financial Reporting Standards (IFRS) for the documentation of valuation information?
10) Different countries may have different valuation units, value types and definitions, processes, etc. Can LADM Part 4 - Valuation information, through its terms, definitions and information model, contribute to communication between different stakeholders in the valuation/LA domain? Does your country plan to use/implement LADM Part 4? Are you planning to use LADM Part 4 to develop an information technology product? How can LADM Part 4 - Valuation information be further improved (more profiles, e.g., different property types, spatial analysis to derive information; more detailed inclusion of information on parties in valuation processes, etc.)?

4. POSSIBLE SOLUTIONS

Has there been any progress/interest in research on the value function of LA in recent years? An increasing number of international guidelines and research papers show that LA researchers are interested in the valuation of LA. It is also a good development that the scope of LADM has been extended to include valuation information. Nevertheless, the number of research papers is still small compared to other functions and research areas of LA. It can be indicated that we are at the beginning of a process.

If land valuation research is indeed to be increased, there are a number of ways in which this could be achieved, including raising awareness of the importance of valuation research issues and discussing what the key research questions are. Examples of possible research include:

1) Collection, derivation, management, processing and updating of input and output valuation information
2) Compliance of local practices and processes with international standards and guidance documents
3) Inclusion of an international perspective on publications
4) Investigation on how valuation information can be better visualized and disseminated to the public
5) Leveraging the latest technologies (e.g., AI/ML, computer vision, data analytics, etc.) to better estimate, collect (extract, derive), visualize and share value and related information
6) Carrying out comparative studies on land valuation concepts and processes

In order to increase the number and quality of the research, it may be a promising idea to collaborate with researchers from economics and statistics departments who have a different background and a distinct perspective on land valuation. Furthermore, it may be useful to note that LADM Part 4 - Valuation information can facilitate communication between stakeholders, international comparisons of valuation processes and the development of new products. It should be mentioned here that the ISO process to publish LADM Part 4 as an international standard is still on going. We like to encourage the researcher to support/contribute to the development of LADM Part 4 through national ISO bodies or FIG.

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BIOGRAPHICAL NOTES

Abdullah Kara holds a Ph.D. degree from Yıldız Technical University (YTU) with a thesis on the extension of Land Administration Domain Model (LADM) with valuation information, which is used as a basis for the development of LADM Part 4 - Valuation information. He is currently working as a post-doctoral researcher at the GIS Technology Section, Delft University of Technology. He has been actively involved in FIG working groups.

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The 11th international workshop on the Land Administration Domain Model and 3D land administration was organised in Gävle, Sweden, 2023.

The Workshop addresses developments in the the following areas:

- **3D Land Administration System operational experiences (analysis, LADM based, learn from each other, discover gaps)**
- **3D LAS cost effective workflow for new / updated 3D parcels = 4D (part of whole spatial development lifecycle: from planning / design / permit in 3D, to registration / use in 3D)**
- **3D LAS web-based dissemination (usability, man-machine interfaces, including mobile/AR)**
- **Remote sensing (including LiDAR) and artificial intelligence (AI) for efficient 3D cadastral boundary extraction**
- **Legal aspects for 3D LAS, best legal practises in various legislation systems**
- **Focus on large cities, including developing countries**
- **3D in the revision of ISO 19152, the Land Administration Domain Model**
- **Proposals for (and evaluations of) LA (remote) sensing information models**

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