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Requirements and Opportunities for Web-Based 3D Visualization and Dissemination of Property Valuation Information

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Key words: Property valuation, ISO 19152 Land Administration Domain Model (LADM), Valuation Information Model, 3D visualization, Dissemination.

SUMMARY

The timely and effective dissemination of property values is an essential part of a transparent and efficient property valuation system as property values are required in several land administration processes, such as land acquisition, taxation, transaction, consolidation, readjustment and transformation. In the last decade, a web-based data-sharing system has been increasingly used for dissemination of property values. The 3D visualization of valuation units may be required in order to better communicate with users and provide more effective and efficient dissemination, however, none of those systems share valuation information associated with 3D representation (legal or physical) of property (valuation) units.

The objective of this paper is to reveal the requirements, opportunities and challenges for web-based 3D visualization and dissemination of property valuation information. To deliver this objective, the requirements for U(ser), D(ata), and V(isualization) are investigated. The general public/property owners and professionals are determined as main user groups in this research. For each of the groups specific data and 3D visualization requirements are discussed and a number of suggestions are provided for developing an effective dissemination of property valuation information. These requirements includes the visualization of multi-part properties (e.g. condominium unit, storage unit, car parking), thematic mapping of valuation information, and aggregation of valuation units into valuation units groups. Furthermore, the capabilities of the LADM Valuation Information Model as a schema for storage, and the features and functionalities of 3D visualization platforms (geoweb viewers) in terms of better value dissemination (e.g. altering visual variables, solution for occlusion, visualizing below surface properties) are briefly investigated. Lastly, an initial prototype is developed and presented.

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1. INTRODUCTION

Immovable property value is a key component of land administration systems (UN-Habitat 2021), as it is important for effective land acquisition, taxation, transaction, consolidation, readjustment, transformation and so on. 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. Lozano-Gracia et al. (2013), for example, stated that urban transformation is most efficient when land markets are grounded in strong institutions that enable public dissemination of property values across users. Furthermore, the New Urban Agenda encourages the use of geospatial visualization opportunities for dissemination of timely and reliable geospatial information (UN, 2016).

Dissemination of input and output data related to property valuation processes is of vital importance for market transparency and reliability. While input data for valuation is likely to include transaction prices (e.g. sale price), sales statistics, and legal, locational and physical property characteristics; the output data is estimated (assessed) values.

In the last decade, valuation information is increasingly disseminated in digital form through the Web. According to the respondents of a questionnaire (isoladm.org, 2017), which was conducted for creating a worldwide inventory revealing commonalities and differences among property valuation systems, a web-based data-sharing mechanism has been used for dissemination of property values (to all public or only to owner of property) in several countries (e.g. Cyprus, Denmark, Singapore, Slovenia, Spain, the Netherlands and the United Kingdom). It should be noted that none of those web-based mechanisms (systems) share valuation information associated with 3D representation (legal and/or physical) of property (valuation) units. In the Netherlands, for example, assessed values together with valuation dates and some characteristics (e.g. construction year, property function/type, floor size) of residential properties are publicly disseminated through footprints of apartment buildings (see 'WOZ-waardeloket' - https://www.wozwaardeloket.nl/). However, visualization of 3D valuation units may be required in order to disseminate valuation information more effectively and efficiently.

Current property valuation practices seem not to be significantly benefiting from semantically rich 3D building and cadastral models (Isikdag et al., 2014; Cagdas et al., 2016; Kara et al., 2020; Ying et al., 2021). They can be, for example, utilized to obtain characteristics of valuation units in order to improve the results of valuations. Moreover, as 3D building and cadastral models include physical and legal boundaries of property units, they can be used for disseminating of valuation information more effectively. In other words, an identical and/or modified version of a 3D cadastral prototype can be used for disseminating property valuation information. In fact, some of recently developed 3D cadastral prototype examples include value as a characteristic of property units. However, it was not researched whether an identical or a modified version of a 3D cadastral prototype can be considered as an effective tool for dissemination of valuation information.

To the best of authors' knowledge, there is no prototype system designed for effective dissemination of valuation information through 3D valuation units. Moreover, the requirements and possibilities to develop an effective dissemination system for valuation information were not investigated. The objective of this paper is to reveal the requirements, opportunities and challenges for web-based 3D visualization and dissemination of property valuation information. To achieve this goal, the studies specifying the requirements for the purpose of developing a 3D cadastral prototype are firstly analysed in Section 2. Subsequently, specific requirements for visualization and dissemination of valuation information are researched in Section 3. In this phase, a number of suggestions are provided for developing an effective dissemination of property valuation information. Moreover, the capabilities of LADM Valuation Information Model as a schema for storage, and the functionalities of 3D visualization platforms (geoweb viewers) in terms of better value dissemination are also briefly investigated in the same section. The conclusions are given in the last Section.

2. OPPORTUNITIES AND REQUIREMENTS FOR WEB-BASED 3D VISUALIZATION AND DISSEMINATION

Valuation processes require correct, complete, and up-to-date information related to property units (International Association of Assessing Officers – IAAO, 2013). This information includes legal, geometric, physical, locational and environmental characteristics of property units combined with transaction prices. It should be noted that the land and building property rights to be valued is the fundamental and indispensable information for valuation processes (IAAO, 2014). Therefore, it can be stated that land registry and cadastre are the main data sources for valuation processes, as they record the rights, restriction and responsibilities (RRRs) and their associated spatial units. In fact, the concept of cadastre emerged for taxation purposes and its aim was to record the land values of spatial units subject to land tax and to identify the related taxpayers (Silva and Stubkjær, 2002). However, it developed from being a fiscal cadastre primarily as a basis for property valuation and taxation to a legal cadastre late in the 1800s (Enemark and Sevatdal, 1999). Today's cadastral systems may serve legal purposes or legal and fiscal purposes. Today's cadastral systems generally store boundaries of property units in 2D and it's legal information, whereas today's valuation processes also require 3D property units with detailed characteristics (Cagdas et al., 2016).

In the last decade, several visualization and dissemination prototype systems have been developed for 3D cadastres providing some advantages over 2D, such as better support for complex multi-level properties, more realistic view of real world and more effective communication with users (Pouliot et al., 2018). In some cases, a 3D cadastral visualization prototype can be directly utilized for disseminating valuation information. However, this is not always the case. In some countries, the basic legal units may differ from the basic valuation units (Cagdas et al., 2016). Additional specific features and functionalities may be required to disseminate valuation information more effectively. The requirement analyses conducted to develop a 3D cadastral visualization prototype system can be adapted for design and development of a prototype for valuation information, because they are using identical or very similar spatial units (e.g. parcel, building, condominium, accessory part).

Several studies investigated the visualization requirements for 3D cadastral systems (Shojaei et al., 2013, 2015, 2018; Wang, 2015; Pouliot et al., 2018; Cemellini et al., 2020). Those studies were selected for this research based on expert consultations and recommendations. Table 1 presents the selected 3D cadastral visualization requirements that are compiled from Pouliot et al. (2018), Shojaei et al. (2018) and Cemellini et al. (2020). Pouliot et al. (2018) grouped the requirements into three categories, namely users and user requirements, information to visualize and semiotic/rendering aspect, and visualization platform.

Table 1. Requirements for 3D cadastral visualization

Users and user requirements	- Property registration authorities, lawyers, notaries, engineers, architects, developers, real estate agents, surveyors, general public, etc. - Descriptions of 3D geometric boundaries of property units (e.g. physical and legal spaces and boundaries) can be included and identified - Private and common parts in 3D co-ownership apartment buildings can be distinguished and represented - -D measurements can be performed and processed - Geometry and characteristics can be queried and compared - Interactive 3D user interface is available - Interoperability with other applications (e.g. property valuation) can be supported
Data and semiotics	- Descriptive and/or legal documentation (e.g. data sources) can be included - Temporal aspects of property rights can be managed - Annotations, labelling, and characteristics are supported in a flexible way - Setting graphic visualization is supported (e.g. colour, texture and transparency) - Highlighting techniques (e.g. slicing, cross-sections, wireframe, explode view, discretization) are available
Visualization platforms	- Platform support: Web/desktop, virtual/augmented reality, game engines, open/proprietary, fully functional editing/basic visualization only - Functionality of the platform include zoom in/out, pan, symbol, colour, line style, thickness, transparency, shadow effect, navigation, tooltip, spatial search, attribute query, spatial analysis, underground view, handling massive data)

The first question that arises in defining the requirements of a visualization and dissemination prototype is "who are the users?" (Pouliot et al., 2018; Shojaei et al., 2018; Cemellini et al., 2020). The property registration authorities, lawyers and notaries are specified as the main user groups for 3D cadastral visualization systems in the selected studies. In accordance with the needs and demands of the user groups, the 3D visualization requirements can be specified.

Describing 3D legal boundaries of property units (e.g. parcel, building, and condominium) is specified as the main aim and the initial requirement for a 3D cadastre. Moreover, the boundaries of private and common parts should be properly distinguished in case of apartment (condominium) buildings. Performing and processing of 3D measurements, spatial analyses and querying geometries and attributes of property units is required. For these analyses and queries, the physical boundaries and characteristics of a building are often of the same importance as the legal boundaries of the parcel on which this building is built. Therefore, it is expected from a cadastral visualization prototype to have such features, and to show the results of demanded analyses.

Next appropriate data sources need to be determined. Various data sources have been used to get 3D volumetric objects. However, creation and maintenance of a valid 3D cadastral object is a challenge in practice (van Oosterom, 2013; Ying et al., 2015). Architectural drawings have long been used to represent apartment complexes in cadastral systems (van Oosterom et al., 2018). Meulmeester (2019) compared the use of 3D BIM/IF to the use of 2D drawings of floor plans in the notarial deed to define 3D legal spaces for apartment rights in the Dutch cadastre. Višnjevac et al. (2019) utilized the drawings of floor plans and cross-sections as data source. Similarly, Atazadeh et al. (2017) used 2D architectural floor plans and cross-section diagrams to create 3D building elements (e.g. walls, doors). It is expected that in near future these architectural floor plans as a base for the 3D system for new buildings can be substituted by BIM-models. However it is frequently the case that the implementation of the design in reality differs from the design in architectural drawings (van Oosterom et al., 2018). Therefore, 'as-designed' models should be verified after construction since 'as-built' models provide ownership boundaries in the real world (Atazadeh et al., 2017).

On the other hand, a number of studies directly utilized surveying data as input for creating 3D cadastral objects. For example, 2D survey plans that provide implicit information to build a representation of 3D cadastral spaces were used by Ying et al. (2011). The information in survey plan documents was converted into 3D geometry as collections of polyhedrons by Cemellini et al. (2020) to develop a LADM compliant dissemination and visualization system for 3D spatial units. Moreover, Li et al. (2016) used 2D layout plans to model the ownership structure of condominium units in 3D. Besides spatial information, the textual (descriptive) characteristics of property units can be extracted from legal documents, such as floor areas, co-ownership shares and use/function type(s). The descriptive information can be visualized as a characteristic associated with relevant property units, using lists, labels, and annotations. It should be indicated that a suitable data schema is required to store both spatial and textual data. For this purpose, ISO 19152:2012 Land Administration Domain Model (LADM) compliant data schemas (an extended version of the LADM with country specific situations) were generated in recent studies (Meulmeester, 2019; Cemellini et al., 2020; Alattas et al., 2021). It is noted that in order to improve the communication level with the users, different highlighting techniques (e.g. slicing and explode view), visual variables (e.g. colour, transparency) and cadastral symbols may also be required (Pouliot et al., 2018).

The last category is on the selection of a suitable visualization platform, considering the above-mentioned requirements of 3D cadastral visualization. Data, users, and usages are important factors to be considered in choosing a visualization technique (Shojaei et al., 2013). In order to display 3D cadastral objects to users, different display modes can be selected, ranging from those available on desktops, standard computers (e.g. gaming engines) or mobile devices (such as a tablets through augmented reality) to those requiring very specialized hardware (Pouliot et al., 2018). On the other hand, web-based display solutions for 3D cadastral visualization prototype systems have been identified as an important visualization requirement among end-users, such as general public and land surveyors (Shojaei et al., 2015). A number of studies investigated the 3D web-based visualization platforms in terms of identified requirements. For example, Shojaei et al. (2013) compared desktop and web-based visualization platforms, while Shojaei et al. (2015) evaluated common 3D web-based visualization solutions, including Web Graphics Library (WebGL) solutions. Moreover, Cemellini et al. (2020) investigated the existing WebGL platforms (e.g. iTowns, Cesium JS, OSM Buildings, WebGL Earth, GeoBrowser 3D, ESRI CityEngine) for developing a 3D cadastre prototype.

WebGL is a royalty-free web standard for a low-level 3D graphics application programming interface (API) (Kronos, 2021). It enables web content to use an API based on the OpenGL for Embedded Systems (GLES) to perform 3D rendering in an HTML canvas in browser. A big advantage of WebGL is that it brings 3D to the Web without any third party plugins since most browser vendors are member of the related WebGL Working Group (Kronos, 2021). As WebGL is a low-level JavaScript API, designing an elementary 3D geometry needs a lot of work; therefore, various open source JavaScript libraries and platforms have been developed to make it easy to use (Shojaei et al., 2015).

From investigation of the recently developed 3D cadastral visualization prototype systems, it is clear that WebGL based libraries and platforms are preferred increasingly. Shojaei et al. (2015, 2018) utilized the Three.js library for developing a 3D visualization prototype. Among the WebGL libraries, CesiumJS is increasingly being used in the cadastral domain (Meulmeester, 2019; Višnjevac et al., 2019; Cemellini et al., 2020; Olfat et al., 2021). It supports 3D tiles enabling to stream massive 3D geospatial data (CesiumJS, 2021). Cemellini et al. (2020) indicated that in addition to being cross-platform and cross-browser, the existence of a big community supporting developers is an advantage of CesiumJS. It should be noted that all functions given in the Table 1 are supported by CesiumJS (e.g. underground view functionality was recently added).

3. SPECIFIC REQUIREMENTS FOR 3D VISUALIZATION AND DISSEMINATION OF VALUATION INFORMATION

To specify specific requirements and extra functionalities of an effective and web-based prototype system for 3D visualization and dissemination of valuation information, the user approach as from the previous section is also followed here. The initial step of the user approach is to determine the users. In our case, main users are considered the appraisers performing private or public valuations and the customers of these valuations, therefore, requirements are specified for the public dissemination of valuation information. These user groups have no specific experience with using 3D models and can therefore be dealt with as "the general public". The importance of 3D systems and 3D data for valuation and mass valuation will grow because of the development of new valuation methods based on Artificial Intelligence (AI). These AI-models make it possible to use the data from the 3D comparison in the estimation of the value.

Similar to the investigated 3D cadastre prototype systems, legal boundaries of valuation units have a great importance for an effective 3D visualization and dissemination of valuation information. Distinguishing private and common parts (spaces) in condominium buildings is another crucial requirement. Moreover, each part of a multi-part property (e.g. condominium unit, storage unit and car parking) should be clearly identified as they may have a separate value. Figure 1 presents an example illustrating the legal spaces (i.e. private, common and accessory) of a condominium unit within a condominium building. It is noted that 3D city and/or building models can also be used to share values of units (e.g. when the basic registration units of a cadastral system are different from the basic valuation units). On the other hand, it should be stated that having option to visualize both legal and physical spaces of valuation units in the same prototype system would further support effective dissemination.

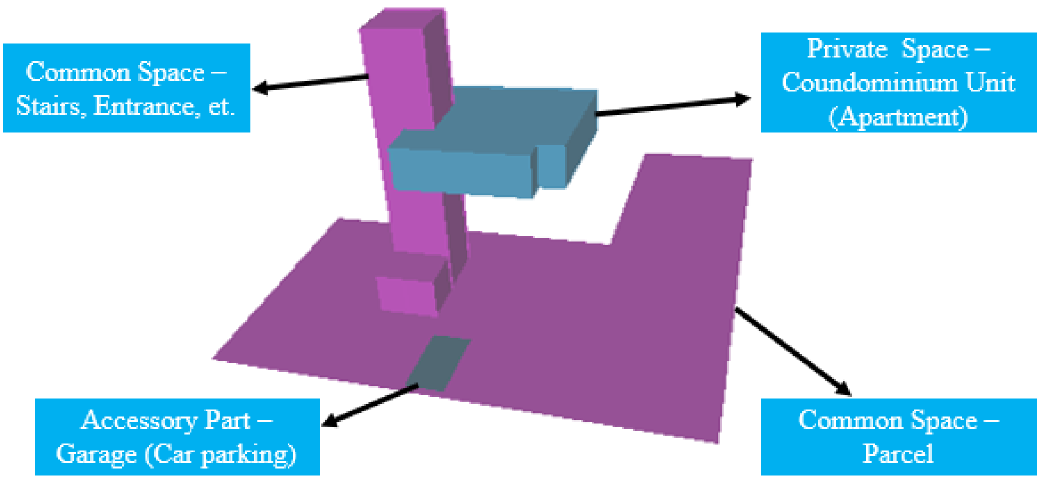

Figure 1. Legal spaces of a condominium unit

In the user requirement phase, the characteristics to be shared should also be determined. The main characteristic to be disseminated is the value of property units. Several different value types (e.g. tax value, investment value, registered value) can be shared via a prototype. However, sharing market value may be preferred over the other value types as the market value can be utilized in different applications which make the dissemination more efficient. The date of valuation can be considered as one of the indispensable characteristics to be shared together with the value. Sharing time series of values of valuation units and valuation unit groups is also expected in an effective prototype.

The valuation units can be aggregated according to use type (e.g. residential, commercial, retail, etc.) and valuation unit group type (e.g. single unit, building, street, neighbourhood, city district, and city) (see Figure 3). Aggregating valuation units into groups (total value of the group, average value per unit within the group) can be considered as the implementation of the level of detail concept in visualization and dissemination of valuation information. At all designated levels, valuation units can be firstly grouped according to use types, and for each use type, for instance the minimum, maximum and average values can be shared.

For the purpose of transparency and accuracy, it is required to disseminate the internal and external property characteristics that are used when calculating values. According to Sirmans et al. (2005), the most frequently utilized internal characteristics in valuation models are building age, floor area, parcel size and accessory parts (e.g. garage space). Therefore, it is needed to include and disseminate those characteristics. By sharing the mentioned characteristics to the public, possible incorrect inputs in calculated values can be eliminated and valuation results may be improved. For the same reason it can also be beneficial to include market data such as sales prices and date of sale in the system. Some of the external property characteristics may also be disseminated as textual data, such as view and distance to important points of interest. A better alternative to this is to develop a prototype that can perform dynamic 3D view and distance analyses. In such a prototype, it is possible to visualize the air space of properties through performing 3D measurements.

After the specification of users and their requirements, appropriate data sources can be determined. Similar to 3D cadastral prototype systems, cadastral plans, surveying plans, floor plans and architectural drawings (or when available BIM models of the buildings) can be utilized to represent valuation units in 3D. The required property characteristics determined above can also partly be derived from those plans and drawings. The actual challenge here is finding ways to visualize all valuation units in 3D, for example, in a neighbourhood or a district. According to the required spatial and textual data specified above, a suitable data schema (application schema) should be produced in this phase. Since the only information model that refines RRRs is the LADM, the data schema should be compliant with it. The LADM can be combined with building models if physical spaces of valuation units are desired to be included in the visualization and dissemination prototype. It should be noted that all the required characteristics of valuation units specified above (e.g. building age, floor area, accessory parts, view, distance) are included in the LADM Valuation Information Model (Kara et al., 2020). Moreover, it covers detailed definitions on valuation units, valuation unit groups and types of usages. Therefore, an extended version of the LADM Valuation Information Model (i.e. country profile) can be directly utilized as a schema for storage of all input and output data used and produced in valuation processes. It can also be used as basis for visualization of legal spaces of 3D valuation units as it is based on the LADM (Kara et al. 2021).

Selecting a visualization platform (geoweb viewer) that conforms to the requirements is the last stage of the user approach. Only WebGL based tools are evaluated in this stage (e.g. CesiumJS, OSM Buildings, ESRI CityEngine, iTowns,) as the aim of this research is to find an appropriate, web-based solution for visualization and dissemination of valuation information. The following aspects are considered as being important when selecting the viewer:

- support for altering visual variables (e.g. colour and transparency) to create coloured 3D valuation maps,
- support for thematic mapping and animations to enable effective dissemination of valuation information,
- support for visualizing below surface properties to identify valuation units below ground level,
- provide some solutions for occlusion to identify valuation units in complex buildings,
- support for 3D measurement to perform spatial analyses (e.g. view),
- support for 3D Tiles to stream massive amounts of data.

According to the above criteria, two geoweb viewers (renderer) came forward, namely CesiumJS and NASA-AMMOS/3DTilesRendererJS. In our case, CesiumJS was selected for visualization and dissemination of valuation information since:

- it provides a complete and end-to-end platform for visualizing, tiling, and analysing 3D geospatial data,
- 3D Tiles formats are also developed by the same group,
- it provides opportunities with 3D analysis tools for distance and area measurement, line of sight, viewshed and visibility analysis,
- it supports time dynamic visualization by means of the CZML format,
- it is widely used in the domain of land administration, it is used by a large group of users.

After the users, users' requirements, data sources, schema for storage and appropriate geoweb viewer are determined, the obtained information is used to create a web-based 3D visualization and dissemination prototype for valuation information. Figure 2 shows a CesiumJS based LADM Valuation Information Model compliant prototype system for valuation information (see: http://3d.araziyonetimi.org/). The legal spaces of valuation units can be identified with the prototype. Moreover, it is possible to distinguish private and common parts of a building. When hovering over a condominium unit, the colour of the accessory part of it (in this case a garage) is automatically changing. When clicking on a condominium unit, valuation information related to the selected unit appears as a table on the left side of the screen.

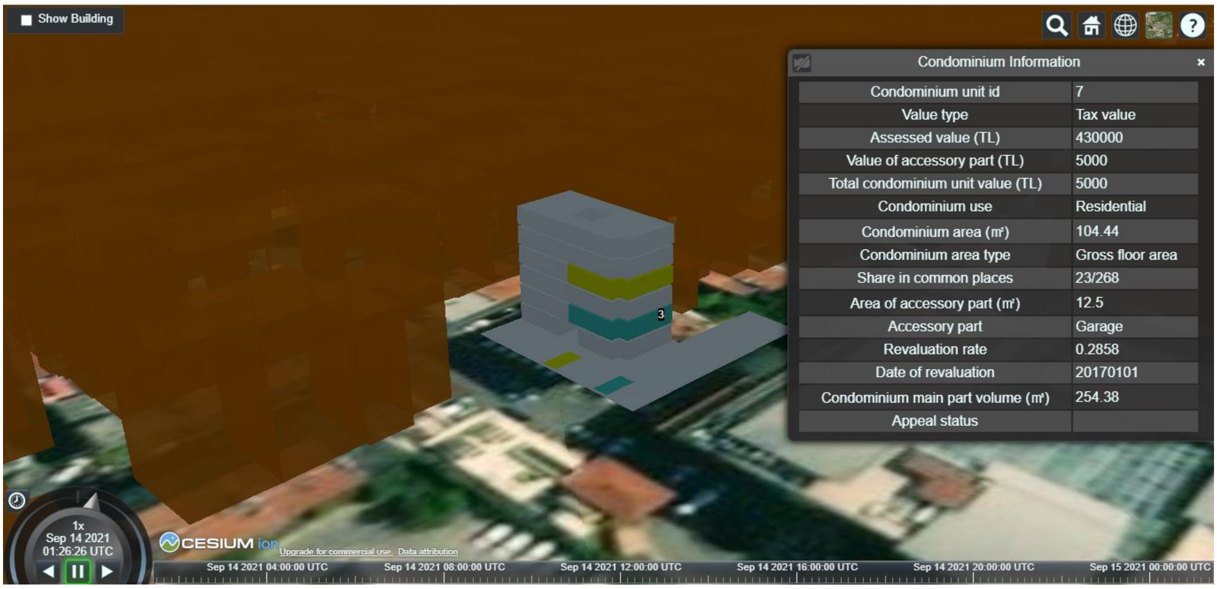

Figure 2. A web-based 3D visualization prototype for disseminating LADM Valuation Information Model compliant valuation information

Besides valuation units, valuation unit groups are also refined in the LADM Valuation Information Model. An application schema that is developed has the capability to store valuation unit groups.

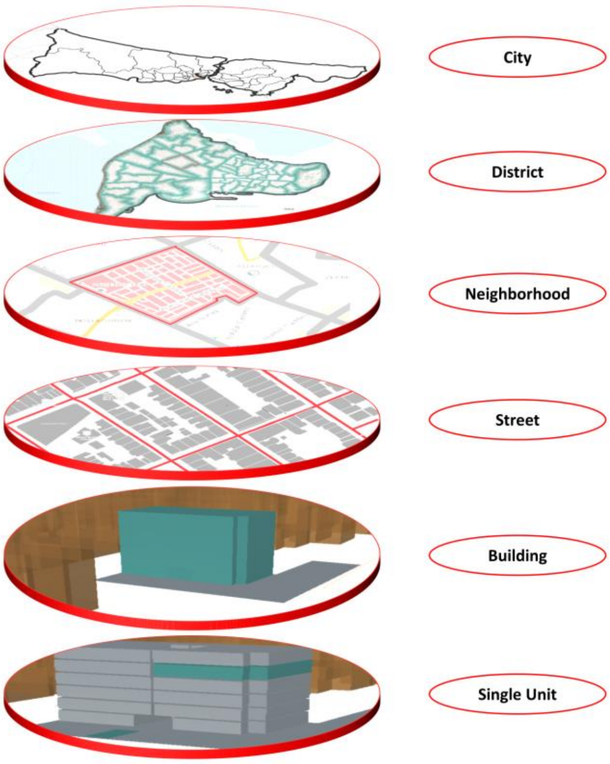

Figure 3. Aggregation of valuation units into valuation units groups

The prototype presented above can also be used to visualize different aggregations of valuation units, if appropriate rules are defined in the prototype. Figure 3 shows a possible classification for the aggregation of valuation units into valuation units groups. It should be noted that since there is not enough data, not all the levels given in Figure 3 are implemented in the prototype.

In Figure 4, the developed prototype is used to create a 3D valuation map for a neighbourhood in accordance with the values of a specific valuation date. The values coloured are aggregations of values of all condominium units in one building (average values can alternatively be used). It should be noted that the building marked with a green circle contains the condominium unit with the highest tax value.

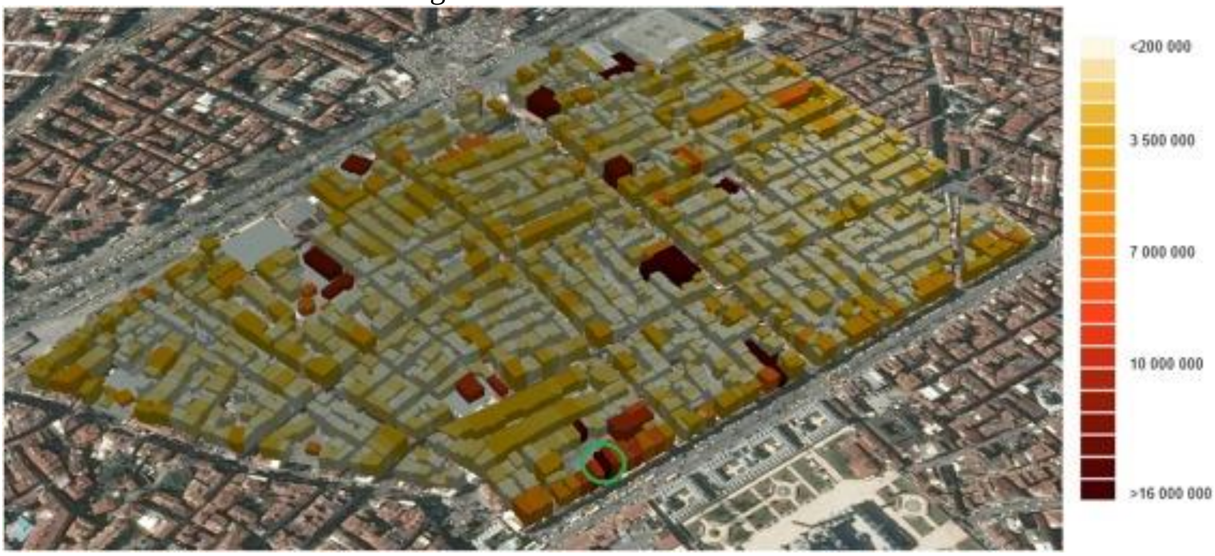

Figure 4. A web-based, 3D and LADM Valuation Information Model compliant valuation map of a neighbourhood (Kara et al., 2021)

4. CONCLUSION

Complete delivery of the 3D land administration theory, together with its practical implementation, is a multi-disciplinary problem (van der Molen, 2002; van Oosterom et al., 2020). One component of this theory is property valuation and this paper focuses on 3D visualization and dissemination of valuation information.

Developing a web-based system for visualization and dissemination of 3D valuation units and their characteristics is a challenging task. To support this task, the defined problem in this paper, which is to search the requirements, opportunities and possibilities for developing a web-based 3D visualization and dissemination system for property valuation information, is broken down into small steps. In the first step, the experience gained from the studies that developed a 3D cadastral visualization prototype are investigated. Subsequently, this experience is applied to valuation information. The general public, without specific experience with 3D models is selected as main user group. This group includes valuers for private valuations and mass valuations as well as their clients. After that the requirements for this user group is discussed together with possible data sources. The requirement analysis shows that the LADM Valuation Information Model compliant schema can be used for data storage and visualization. In the last step, considering the specific functionality requirements, geoweb viewers are investigated and CesiumJS was selected as an appropriate option.

The paper makes a number of suggestions for effective visualization and dissemination of valuation information, such as aggregation of valuation units into groups (e.g. level of detail in visualization of valuation information). Finally, taking into account the requirements analysis, a prototype system is developed and presented. However, it should be noted that the developed prototype is not completed yet and there is a lot still to be done. For example, the prototype system should be enriched with some functionalities and needs to be tested with a more complete dataset.

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