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Kara, Abdullah; van Oosterom, Peter; Kathmann, Ruud; Lemmen, Christiaan

DOI
10.1016/j.landusepol.2023.106829

Publication date
2023

Document Version
Final published version

Published in
Land Use Policy

Land Use Policy 132 (2023) 106829

Contents lists available at ScienceDirect

Land Use Policy

journal homepage: www.elsevier.com/locate/landusepol

Visualisation and dissemination of 3D valuation units and groups – An LADM valuation information compliant prototype

Abdullah Kara [a,*], Peter van Oosterom [a], Ruud Kathmann [b], Christiaan Lemmen [c]

[a] Faculty of Architecture and the Built Environment, Delft University of Technology, Julianalaan 134, 2628 BL Delft, the Netherlands
[b] The Netherlands Council for Real Estate Assessment, P.O. Box 93210, 2509 AE The Hague, the Netherlands
[c] Faculty of Geo-Information Science and Earth Observation (ITC), University of Twente, Hengelosestraat 99, 7514 AE Enschede, the Netherlands

ARTICLE INFO

Keywords:
Property valuation
ISO 19152 Land Administration Domain Model (LADM)
LADM Part 4
Valuation information
3D visualisation
Dissemination
Price index

ABSTRACT

The timely and effective dissemination of property values is an essential part of a transparent and efficient property valuation system. Over the last decade, web-based data-sharing systems have been increasingly used for the dissemination of assessed property values. 3D valuation units (e.g., condominium) and groups (aggregation of valuation units, e.g., a building floor in a multi-occupied building, a multi-occupied building, street, district or valuation zone) may be required to better communicate with users and to support a more effective and efficient dissemination. However, none of these systems share valuation information associated with 3D representation of the valuation units and groups. In this paper, a prototype of a web-based system is developed utilising the proposed Valuation Information part of the Edition II of the ISO 19152 Land Administration Domain Model compliant dataset for not only disseminating the spatial, physical, thematic and temporal characteristics of 3D valuation units, but also for sharing the valuation statistics at each designated level and with level-specific attributes. It is expected that the outcomes of this work may contribute to the development of local or national valuation systems and systems for geo-based data visualisation for effective and efficient sharing of valuation information. As such, it is anticipated that the study's outcomes will not only increase the level of communication with the public, but also support politicians and planners in their decision-making processes and help them to better analyse and understand the property market. With the proposed system, confidence in valuation results can be further increased due to the high level of transparency.

1. Introduction

Immovable property value information is a key component of land administration systems (UN Habitat, 2021), as it is important in support to effective land transactions, land taxation, land consolidation, land readjustment and urban transformation. The timely and effective dissemination of property values as well as input information related to the valuation processes to the 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 visualisation opportunities for the dissemination of timely and reliable valuation information (UN, 2016).

Interest in utilising 3D data in property valuation has increased over the last decade. The use of 3D data models (3D cadastre (e.g., ISO 19152 LADM), city model (e.g., OGC's CityGML), building information model – BIM (e.g., ISO 16739 Industry Foundation Classes – IFC)) in the field of valuation can be basically grouped in two main categories: (a) supporting mathematical models with variables generated by 3D analyses (e.g. view, insolation, noise) in order to better estimate the values of properties and (b) visualising valuation units[1] in 3D and disseminating the values of properties associated with the visualised units (legal or physical space). It is observed that the studies in the literature mostly focus on supporting the valuation processes by deriving variables from 3D data models in order to improve the valuation results (Tomić et al., 2012; Isikdag et al., 2014; Kara et al., 2020; El Yamani et al., 2021; Ying et al., 2021). These studies are important as Artificial Intelligence (AI) algorithms have now been implemented in the practice of mass

* Corresponding author.
E-mail address: A.Kara@tudelft.nl (A. Kara).

[1] Basic unit that is subject to property valuation process.

https://doi.org/10.1016/j.landusepol.2023.106829
Received 9 June 2022; Received in revised form 12 April 2023; Accepted 18 July 2023
Available online 28 July 2023

valuation, and the characteristics of valuation units derived from 3D data models can be used to calibrate and improve the performance of AI-based mathematical valuation models.

However, the current paper focuses on the latter category in particular. A prototype developed for a purpose other than valuation (e.g., 3D cadastre, BIM) can usually be used to disseminate property values. In such an approach, the property value is included as a simple attribute attached to the unit visualised in 3D (e.g., basic cadastral unit). This approach works well when a visualised unit and a valuation unit represent the completely same object. However, it is not always the case. For example, the basic registration unit in cadastral systems (e.g., cadastral parcel or cadastral apartment right) may be different from the basic valuation unit[2] in some countries, and therefore cadastral systems may not meet the needs of valuation processes and of effective dissemination of valuation information associated with 3D valuation units and groups.

Considering these situations, the ISO 19152 Land Administration Domain Model (LADM) based Valuation Information Model (LADM_VM) has been developed for the specification of valuation information maintained by public authorities. A country profile developed using LADM_VM can be used as a basis for the dissemination of valuation information associated with 3D valuation units (e.g., condominiums) and groups (aggregation of valuation units, e.g., building floor in multi-occupied building, multi-occupied building, street, district, valuation zone and so forth). Publishing the statistical data associated with the 3D units can enable more effective communication with users. In addition, a prototype with 3D data can clearly demonstrate which dataset is used to calculate statistical analysis. Showing the statistical data in 3D may also reveal the differences or not per level (in case data is aggregated per level) or what is the effect of building height on the value of the properties in the building.

To the authors' knowledge, there is no (prototype) system specifically designed for the effective dissemination of valuation information through 3D valuation units, and valuation statistics through 3D valuation unit groups. The objectives of this paper are (a) to show why a new model (i.e., LADM_VM) other than ISO 19152 LADM is required to represent valuation information, (b) to investigate the requirements for developing an effective dissemination system for valuation information, and (c) to develop an LADM_VM compliant prototype system utilising the open dataset of the Netherlands for the effective dissemination of valuation information.

The remainder of this paper is structured as follows: Section 2 briefly introduces the LADM Valuation Information Model and presents UML instance-level diagrams using the Netherlands country profile of LADM_VM (Kara et al., 2019) in order to show why an extension (i.e., LADM_VM) to the core LADM is needed to present valuation information. The requirements for the development of an effective and web-based prototype for the visualisation and dissemination of 3D valuation units and groups are investigated in Section 3. In that section a classification for the aggregation of valuation units into valuation unit groups is also proposed. More specifically, the distinct levels for valuation unit groups are specified in order to effectively share valuation/sales price related statistics, and for each level individual characteristics (attributes) are proposed (e.g., average values in different years, average building age in the neighbourhood, etc.). Based on the proposed classification, a prototype is developed using the open datasets of the Netherlands in Section 4. All the datasets used in this paper are available to the general public in the Netherlands. The utilised dataset in this paper can be viewed in 2D at Addresses and Buildings Key Register (BAG) viewer[3] and at Value Register (WOZ) viewer.[4] During the development of the prototype, answers are sought to the following questions: (a) how can apartments (condominium units) in a multi-storey building be visualised in 3D without having any plans (e.g., architectural plan, survey plan, as-built plan)? (b) Is it possible and meaningful to visualise them with some assumptions (e.g., 3 m ceiling height) and inferences (e.g., number of apartments per floor, number of floors in a multi-occupied building and orientation (facing direction) of an apartment)? Section 5 presents the conclusions and plans for further research.

2. LADM valuation information – why such an extension necessary?

The cadastre and land registry are the main data sources for property valuation processes, as they record rights,[5] restrictions[6] and responsibilities[7] (RRRs) and their associated basic administrative unit(s),[8] together with spatial units.[9] The property rights to be valued are the fundamental and indispensable information for these processes, and the focus of the Edition I of ISO 19152 LADM is on RRRs affecting the land and water (ISO, 2012). The LADM Edition I does not meet the requirements of representing all the input and output data in valuation processes. Specifically, it has only one external class, ExtValuation, for specifying of valuation information and does not provide detailed information to represent all cases related to valuation processes as it only includes value, value type and value date attributes. For accurate valuations the valuation system must also include data on for instance property type, size and building year as well as information on quality of the property and maintenance condition. In order to refine LADM, LADM_VM has been developed to model valuation information maintained by public authorities. This model was first introduced by Çağdaş et al. (2016) and it has been reviewed, revised and improved by incorporating the comments received during several workshops, including the 7th, 8th, 9th and 10th FIG LADM Workshops (FIG, 2018, 2019, 2021, 2022). The latest version of LADM_VM[10] is designed to facilitate all stages of administrative property valuation, namely the identification of valuation units, the valuation of units through single or mass appraisal procedures, the recording of transaction prices, the representation of sales statistics, and the handling of appeals (Çağdaş et al., 2016; Kara et al., 2018, 2020, 2021a). It is worth noting that the systematic review of the ISO 19152 LADM has started under ISO TC/211 in 2018. One of the new parts in LADM Edition II is designed on the basis of the proposed LADM_VM, will be on property valuation (Part 4 – Valuation Information).

Several country profiles for LADM_VM have been developed so far, such as China (Xu et al., 2019), Croatia (Tomić et al., 2021), the Netherlands (Kara et al., 2019), Serbia (Radulović et al., 2022) and Turkey (Kara et al., 2021a). The Dutch country profile of LADM_VM (Kara et al., 2019) is used to demonstrate why a valuation extension

[2] Object of valuation may be (a) only land parcel, (b) only building, (c) land parcel(s) with/without building(s) together as land property, (d) condominium unit consisting of building part(s) (e.g., condominium main part, condominium accessory part, joint access facility) and a share in land parcel(s).

[3] https://bagviewer.kadaster.nl/

[4] https://www.wozwaardeloket.nl/

[5] Formal or informal entitlement to own or perform an action.

[6] Formal or informal obligation on the land owner to refrain from performing an action.

[7] Formal or informal obligation on the land owner to allow or perform an action.

[8] Administrative entity, which can be subject to registration (by law), or recordation [by informal right, or customary right, or another social tenure relationship], consisting of zero or more spatial units against which, one or more, unique and homogeneous rights, responsibilities or restrictions are associated to the whole entity, as included in a land administration system.

[9] Feature type related to land administration/georegulation with associated spatial and thematic attributes.

[10] The latest version of LADM_VM can be found at https://github.com/ISO-TC211/HMMG

(package) is needed for LADM. Instance level diagrams are drawn to illustrate the capabilities of a LADM_VM based country profile for two use cases.

In the Netherlands, approximately nine million properties are valued annually for levying taxes and other government purposes (Kathmann and Kuijper, 2018). The valuation of property for public purposes is regulated by the Special Act for Real Estate Assessment (Wet Waardering Onroerende Zaken – Wet WOZ, 1995), which was enacted on January 1st, 1995, defining determination and provision of real estate property values for various property taxes (Wet Waardering Onroerende Zaken – Wet WOZ, 1995). The Act authorises all municipalities to assess the value of immovable property, and it is mandatory for public organisations to use these assessed values for various purposes. The Council for Real Estate Assessment (Waarderingskamer), is an independent governmental organisation, supervising the municipalities in the implementation of the Act and monitoring the quality of real estate property assessment (Kathmann and Kuijper, 2018). The estimated market value, namely the WOZ-value (WOZ-waarde), is formally assessed for all types of property (e.g., residential, and commercial).

The WOZ-value is primarily the real market value of a property at a given date. The definition of market value in the European Valuation Standards (EVS) of The European Group of Valuers' Associations (TEGoVA) is used as the basis for the definition of the WOZ-value: "*The estimated amount for which the property should exchange on the date of valuation between a willing buyer and a willing seller in an arm's length transaction after proper marketing, wherein the parties had each acted knowledgeably, prudently and without compulsion*". (TEGoVA, 2016). The WOZ-value corresponds to the market value based on the 'highest and best use', which is the formally allowed use as described in the zoning plan (Bervoets et al., 2016). The WOZ-values of the valuation units (WOZ-object) have been assessed annually since 2007. For the annual property valuation, a valuation date is used that is one year prior to the current year is used; therefore, the assessed value for the year 2018 is based on the real estate market on 1 January 2017 (Bervoets et al., 2016; Kathmann and Kuijper, 2018). In this way, the assessed value is up-to-date and sufficient market data can be analysed to carry out the valuation carefully (Bervoets et al., 2016).

Cadastral registration units can differ from valuation units in some cases in the Netherlands. In fact, the relationship between valuation units (WOZ-objects) and cadastral units (parcels and apartments) is in theory simple, but can be challenging for valuation system. There are for instance several valuation units on a cadastral parcel for the units that are rented out, for instance houses that are rented out by a social housing association or business units in a multi-company building. It should be noted that '*there are about three million rented homes in the Netherlands* and *about 75% of them are owned by housing associations. Social housing is cheaper because it is subsidised by the state.*' according to the official website of the government (Government of the Netherlands, 2022). Fig. 1 shows the relationship between a cadastral unit and (four) valuation units in this case of multiple rented out units. The 'cadastral unit1′ registered in the cadastral database contains four valuation units (WOZ-Object) with four different values (WOZ-Value).

On the other hand, it should be noted that if adjacent buildings or land parcels or apartment rights are owned and used by the same person, then these parcels and buildings and apartments together form a single WOZ-object. This results in a m:n relationship between valuation units and cadastral units. The fact that there can be more than one valuation unit within a cadastral unit is typical for the property tax system in the Netherlands, where both the owner and the user are taxpayers. More common is the case where more than one cadastral parcel is bought by the same owner and combined into a complex.

Given the focus of this work on the Dutch country profile of LADM_VM, the distinction between cadastral registration units and valuation units is only examined within the context of this profile. It should be noted, however, that this issue is widespread globally. In valuations conducted for the purpose of recurrent taxation, for instance, the assessed units may vary depending on the tax base, such as only buildings (improvements), land and buildings combined, or land and buildings separately are considered (Bird and Slack, 2002; Kara et al., 2018).

LADM_VM can also be used to present sales/valuation statistics relating to a group of valuation units (e.g., neighbourhood, municipality, district or country) and use/function types (e.g., residential, retail, office or industrial). For example, LADM_VM can be utilised to construct or display a house price index (HPI), which is an indicator of house price trends in a particular geographical or administrative area between specified intervals. An HPI may have a number of uses, such as a macroeconomic indicator, an input for estimating the value of housing, and for making inter-area comparisons (Eurostat, 2013, p.19). In addition, it also plays a critical role in top-level decision-making, and has an impact on investment decisions (Plakandaras et. al, 2015). A large number of HPIs are produced at regular intervals (monthly, quarterly, and annually) using different methodologies developed by international organisations (e.g., Standard and Poor's,[11] Eurostat,[12] International Monetary Fund (IMF),[13] statistical offices and central banks of countries, land registries and private companies). As indicated by the Eurostat (2013, p. 25), methods for constructing HPIs can be classified into four categories: stratification or mix adjustment, repeat sales method, hedonic regression method, and use of property valuation information. It is worth emphasising that a full technical implementation of LADM_VM allows the construction of HPIs according to the four methods specified by Eurostat.

The Statistics Netherlands (CBS),[14] for instance, reports on monthly price developments of existing owner-occupied dwellings in collaboration with the Cadastre, Land Registry and Mapping Agency (CBS, 2022). According to the CBS, '*the price index is calculated by comparing sales prices in the reporting period with the most recent WOZ value of the dwellings sold.*'.

Fig. 2 shows the instance level diagram produced using the Netherlands profile of LADM_VM (Kara et al., 2019), representing the sales statistics retrieved from data that is available on the CBS website. The class diagram shows the basePriceIndex and dateOfBasePriceIndex attributes to record the value and date for the specification of the base index (e.g., Base Index Value = 100 in 2015 on the 1st of January), and the priceIndex and dateOfPriceIndex attributes to record the calculated price index at a given date (e.g., Index Value = 185.9 at the 1st of 2022 April). The valuation unit group is composed as country since the index is calculated for the entire Netherlands.

It should be noted that LADM_VM also enables to record internal and external characteristics of valuation units (including 3D ones produced through spatial analyses, e.g., view), transaction prices, input data used in single or mass valuation procedures (Kara et al., 2020, 2021a). For this part of the valuation data it is worth noting that in the Netherlands a new registration for physical object characteristics like type, size etc. of buildings, named 'coherent registration of objects' (SOR) is under preparation. The intention is to base the registration as much as possible on the data in the existing registers (e.g., building and valuation), but also to add a 3D component to the data, using the formulated transposition rules that describe how data from the current key registers can be converted to the SOR information model. In this registration the complex relationships between buildings, units within buildings, floors etc. will be made explicit. At Geonovum, they have done a 'high-5 session ' to experiment with existing data to come to a 3D representation

[11] https://www.spglobal.com/spdji/en/index-family/indicators/sp-corelogic-case-shiller/sp-corelogic-case-shiller-composite/#overview

[12] https://ec.europa.eu/eurostat/statistics-explained/index.php?title=Housing_price_statistics_-_house_price_index

[13] https://www.imf.org/external/research/housing/index.htm

[14] https://www.cbs.nl/en-gb

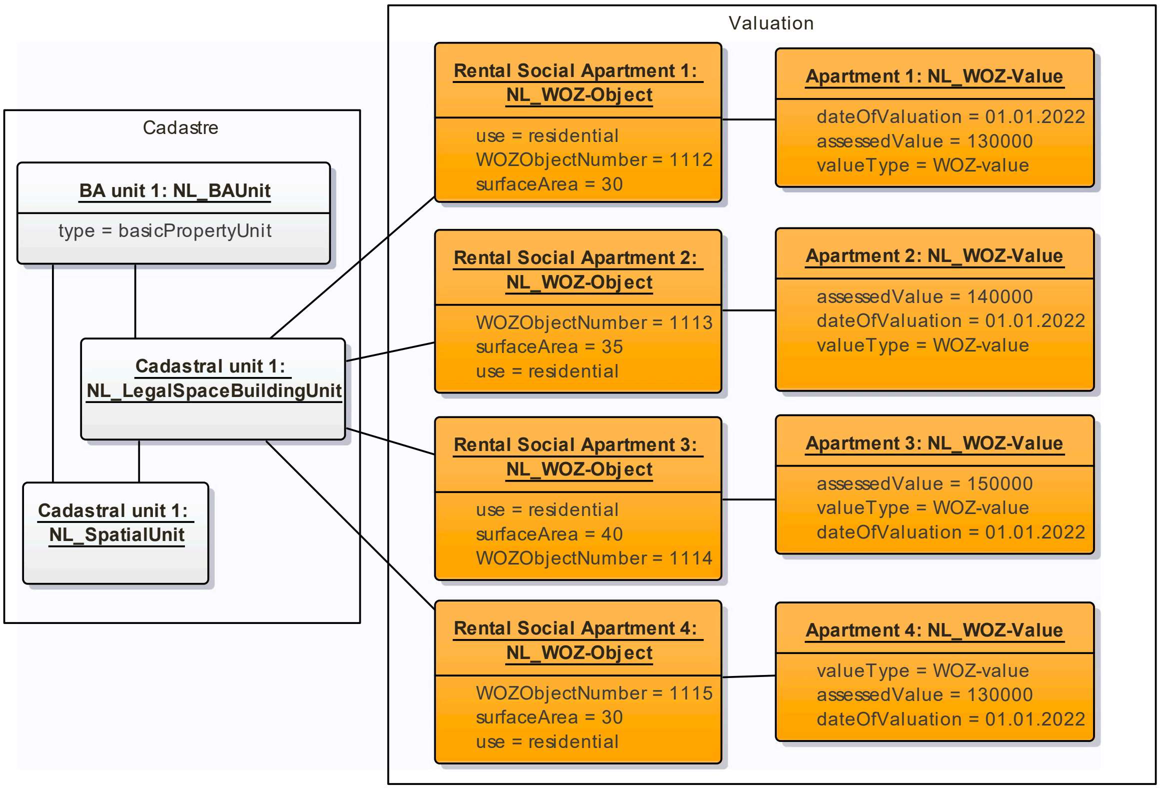

Fig. 1. An example of the relationship between the cadastral units and the valuation units in the Netherlands.

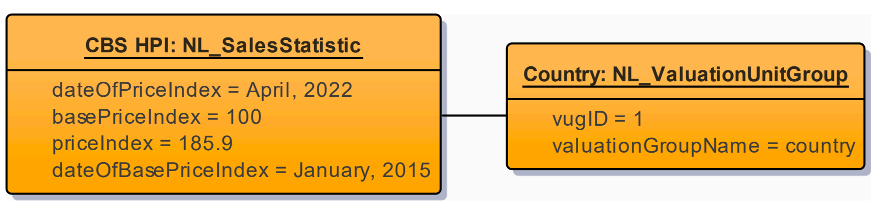

Fig. 2. Instance level diagram of sales statistics in the Netherlands.

including a 3D representation of units within a building.

Furthermore, a country profile developed using LADM_VM can be used as a basis for visualising and disseminating of valuation information associated with 3D valuation units and groups.

3. Requirements for web-based 3D visualisation and dissemination of valuation information

In the last decade, several web-based 3D visualisation and dissemination prototype systems have been developed for various purposes including 3D cadastres which are the fundamental data source for the valuation processes. 3D cadastres have some advantages over 2D, for example better support for complex multi-level properties, a more realistic representation of the real world, and more effective communication with users (Pouliot et al., 2018). In some cases, a 3D cadastral visualisation prototype can be directly utilised for the dissemination of valuation information. However, this is not always the case, as the basic administrative units may differ from the basic valuation units. Moreover, additional specific attributes and functionalities may be required to disseminate valuation information more effectively. On the other hand, the requirements analyses carried out for the development of a prototype system for 3D visualisation of the cadastral information can be adapted for the development of a prototype system for visualisation and dissemination specific to valuation information, since they use identical or similar units.

Several studies have investigated the visualisation requirements for 3D cadastral systems (Shojaei et al., 2013, 2015, 2018; Wang, 2015; Pouliot et al., 2018; Stoter et al., 2017; Cemellini et al., 2020). In order to categorise the requirements and functionalities of an effective and web-based prototype system for the visualisation and dissemination of 3D valuation units and groups, three main categories are identified, inspired from Pouliot et al. (2018), namely users and user requirements, data source and visualisation platform.

The first question that arises in defining the requirements of a visualisation and dissemination prototype is “who are the users?” (Pouliot et al., 2018; Shojaei et al., 2018; Cemellini et al., 2020). For this study, the main users are deemed to be appraisers performing private or public valuations, politicians, planners, and property owners. These user groups may not have any specific experience in using 3D models and can therefore be treated as the general public. Therefore, the identified requirements are based on the needs of the aforementioned user groups, with a specific focus on the general public.

Similar to 3D cadastre prototype systems, legal boundaries play a crucial role in effectively disseminating valuation information. Further it is essential to distinguish between private and common parts (spaces) in condominium buildings (i.e., multi-occupied building) to visualise the legal status within the buildings but also to demonstrate the co-ownership shares which may (dramatically) affect the property value.

Additionally, each part of a multi-part property (e.g., condominium unit, storage unit and parking space) should be clearly identified as they may separately be the subject to a valuation process (e.g., valuation of a parking space). It should be noted that having option to visualise both legal and physical spaces of valuation units in the same prototype system would further support effective dissemination.

In the identification of user requirements, it is also important to determine the characteristics of the valuation units to be disseminated. The primary characteristic to be shared are the values of the units. While various value types, such as tax value and registered value, should be disseminated through the prototype, the market value may take precedence over other value types, as it can be utilised in various applications. The date of valuation is considered an essential characteristic to be shared. Furthermore, an effective prototype is required to share value changes (i.e., time series) and valuation statistics for both individual valuation units and groups of valuation units.

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 floor, building, street, neighbourhood, valuation zone, district, city or country) for efficient dissemination of valuation statistics at each designated level with level-specific attributes. Fig. 3 depicts the proposed classification of valuation unit groups. At all designated levels, valuation units can be firstly grouped by type of use, and for each type of use specific attributes associated with that group can be shared, such as the average value and the annual increase in average value for multi-occupied buildings.

For the purposes of transparency, it may be necessary to disclose the internal and external property characteristics used in the valuation. According to Sirmans et al. (2005), the most frequently utilised internal characteristics in valuation models are building age (date of construction), floor area, parcel size and accessory parts (e.g., garage space). By making these characteristics available to the public, potential errors in valuation can be eliminated and valuation results can be improved. For the same reason, it may also be beneficial to include some of the external property characteristics 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.

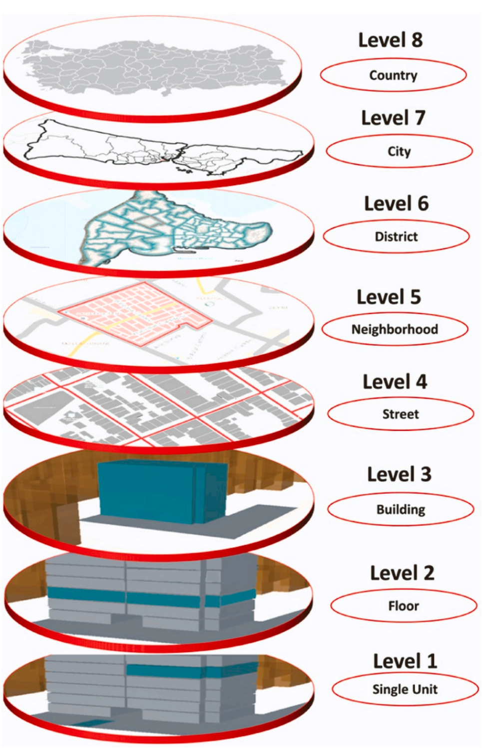

Fig. 3. Aggregation of valuation units into valuation unit groups.

Once the users and their requirements have been defined, appropriate (existing) data sources can be determined. Similar to 3D cadastral prototype systems, cadastral plans, survey plans, floor plans, architectural drawings and BIM/city models (where available) can be utilised to represent valuation units in 3D (with the purpose to derive legal boundaries of valuation units). The real challenge here is to find all the plans, drawings or models to visualise valuation units in 3D, for example in an entire neighbourhood or district. Unfortunately, in most cases this is not the situation. One of the possible solutions is to make some assumptions (e.g., 3 m ceiling height) and inferences using the available dataset (e.g., open cadastral, building, valuation, point cloud and so on).

As one of the requirements for effective value dissemination is to derive legal boundaries of valuation units to distinguish individual and common spaces in multi-occupied buildings, the level of detail (LoD) of buildings becomes important when using BIM/city models as the main data source. The concept of LoD in 3D building (city) modelling has been borrowed from computer graphics, although the meanings are slightly different. In computer graphics, the LoD concept is utilised to generate efficient visualisations from highly detailed data, whereas in 3D building modelling it serves as a specification-based instruction for data collection, modelling, storage, and exchange (Kolbe and Gröger, 2003; Biljecki et al., 2014). One of the widely utilised standards for city modelling is OGC CityGML. This standard defines four consecutive LoDs, namely LOD0 (highly generalised model), LOD1 (block model / extrusion objects), LOD2 (realistic, but still generalised) and LOD3 (highly detailed model) (Kutzner et al., 2020; OGC, 2021). In addition, Biljecki et al. (2016) propose four refined LODs for each of the LoDs (0−3) to allow for less ambiguous definitions of detail for residential buildings. According to the CityGML definitions it can be inferred that the LoD2 may provide enough details to derive/estimate the legal spaces of buildings, but since details related to buildings such as balconies (e.g., open balcony), are neglected at this level (OGC, 2021), additional geometric information may be required. On the other hand, according to the definitions in Biljecki et al. (2016), at least LoD 2.1 or more detailed data may be required to derive legal boundaries, as LoD 2.1 includes not only individual buildings, roof structures and large building parts such as garages, but also smaller building parts and extensions such as alcoves and large wall recesses (see Fig. 4).

In the data source identification, a suitable data schema (application schema) should also be created to store all the data, according to the required spatial and textual data specified above. It should be noted here

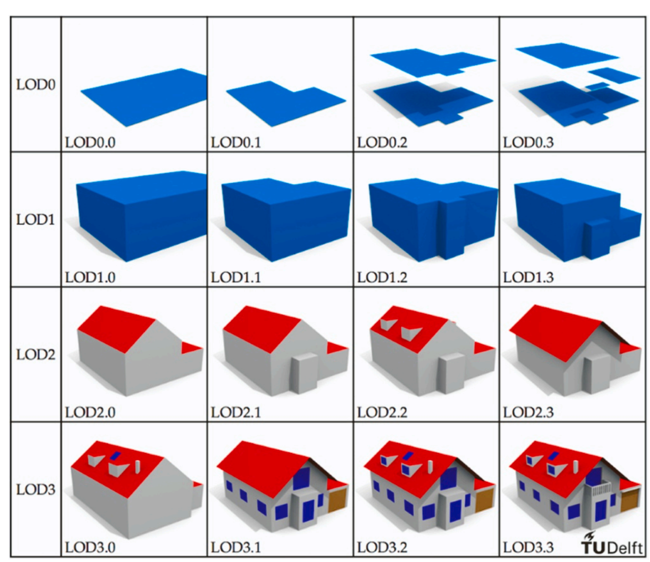

Fig. 4. The visualisation of improved LOD specification for 3D building models (Biljecki et al., 2016).

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, the model covers detailed definitions[15] of valuation units, groups of valuation units and types of use. Therefore, an extended version of the LADM Valuation Information Model (i.e., country profile) can be directly utilised as a schema for storage of all input and output data in valuation processes that can also be used as a basis for visualisation of the legal spaces in 3D valuation units.

The selection of a suitable visualisation platform (geoweb viewer) that meets the above requirements is the last identified category. 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 visualisation and dissemination of valuation information. The following aspects are considered as being important when selecting the appropriate viewer: (a) supports for altering visual variables (e.g. colour and transparency) to create coloured 3D valuation units, (b) supports for thematic mapping and animation to enable effective dissemination of valuation information, (c) supports for visualising below surface properties to identify valuation units below ground level, (d) provides solutions for occlusion to identify valuation units in complex buildings, (e) supports for 3D measurement to perform spatial analysis (e.g. view), and (f) supports for 3D Tiles to stream massive amounts of data.

According to the above criteria, two geoweb viewers (renderers) came forward, namely CesiumJS and NASA-AMMOS/3DTilesRendererJS. In this paper, CesiumJS was selected for visualisation and dissemination of 3D valuation units and groups since: (a) it provides a complete and end-to-end platform for the visualisation, tiling, and analysis of 3D geospatial data, (b) it supports the 3D Tiles format, (c) it provides capabilities with 3D analysis tools for distance and area measurement, line of sight, viewshed and visibility analyses, (d) it supports time dynamic visualisation by means of the CZML[16] format, (e) it is widely used by a large group of users in the domain of land administration.

4. A prototype for visualisation and dissemination of 3D valuation units and groups

The requirements specified in the previous section are utilised to create a web-based visualisation and dissemination prototype for 3D valuation units and groups for the Netherlands. The WOZ-values of residential properties are publicly available on the web in the Netherlands since 2016 for all kinds of private use, as part of a fair and transparent governance. The assessed value together with valuation dates and some characteristics (e.g., construction year, property function/type, floor size) of residential properties (single units) are disseminated through the footprints of apartment buildings, see WOZ-waardeloket.[17] However, as mentioned in the previous section, the efficient dissemination of valuation information may require the visualisation of 3D single (valuation) units. It is also important to share statistical analyses of sales prices / values with the general public and professionals in order to support the property market. The CBS regularly publishes statistical analyses of house price changes. The shared statistical analyses are only textual information, not associated with spatial (legal) part(s) of 3D valuation units and groups. The publication of statistical analyses associated with 3D visualised valuation units and groups can increase the transparency, reliability, and the level of communication between users.

The classification proposed by Kara et al. (2021b) for the aggregation of valuation units into valuation unit groups is further refined with the building floor level in Kara et al. (2022) as the floor level will become part of the new registration SOR in the Netherlands. In this paper, the classification proposed in Kara et al. (2022) is utilised, see Fig. 3.

The designated levels in Fig. 3 may vary in various countries according to administrative classifications and valuation zones. Therefore, each country may add new levels to the proposed structure. Table 1 presents the refined levels and level-specific attributes for the Netherlands. The proposed classification is extended with two additional levels (i.e., province and region) specific for the Netherlands. In addition, a number of attributes is specified for each designated level, considering the valuation processes and the open dataset of the Netherlands.

Based on the requirements identified in the previous section and the proposed classification of valuation unit group, a prototype is developed using the open datasets of the Netherlands. For the prototype, two apartment blocks in the P.J. Oudstraat (both consisting of four adjoining blocks) and eight single-family houses/buildings in the Wiardi Beckmanstraat (see Fig. 5) were selected in Papendrecht, a municipality in the province of South Holland. In the municipality of Papendrecht (15.000 valuation units) the valuation is carried out by a shared service centre, 'Drechtsteden'. The reason for selecting this study area is that the first 4 levels identified in Table 1 can be implemented for different building types (i.e., single and multi-family), and this area can easily be extended to the other levels for future prototyping.

The Netherlands has a standardised and well-established addressing system that is kept and presented in a national dataset called the Addresses and Buildings Key Register (BAG). The information is collected by municipalities and integrated into a form of national base register by

Table 1
Proposed levels and attributes for the value dissemination prototype.

Levels	Attributes
Level 1 – Single unit (condominium, apartment, residence unit)	WOZ-value, valuation date, address, building ID, use (function) type, floor number, floor area, annual increase in value, energy label, …
Level 2 – Building floor (multi-occupied building)	Average WOZ-value, date of calculation of average WOZ-value, average WOZ-value per square metre, average floor area, floor number, annual increase in value, …
Level 3 – Building (multi-occupied building)	Average WOZ-value, date of calculation of average WOZ-value, average WOZ-value per square metre, use (function) type, year of construction, total unit number, min/max floor area, annual increase in value, energy label, …
Level 4 – Street	Street name, min/max construction year, average WOZ-value, date of calculation of average WOZ-value, average WOZ-value per square metre, annual increase in value, …
Level 5 – Neighbourhood	Average WOZ-value, date of calculation of average WOZ-value, min/max year of construction, index value, index date …
Level 6 – District	Average WOZ-value, date of calculation of average WOZ-value, min/max year of construction, annual increase in value, index value, index date …
Level 7 – Municipality	Average WOZ-value, date of calculation of average WOZ-value, min/max year of construction, annual increase in value, index value, index date, …
Level 8 – Province	Average WOZ-value, date of calculation of average WOZ-value, annual increase in value, index value, index date, …
Level 9 – Region	Average WOZ-value, date of calculation of average WOZ-value, annual increase in value, index value, index date, …
Level 10 – Country	Average WOZ-value, date of calculation of average WOZ-value, annual increase in value, index value, index date, …

[15] For detailed definitions, see the LADM_VM UML, available at https://github.com/ISO-TC211/HMMG
[16] https://github.com/AnalyticalGraphicsInc/czml-writer/wiki/CZML-Guide
[17] https://www.wozwaardeloket.nl/

Fig. 5. The photograph of the buildings selected for the prototype.
(Source: Google).

the Cadastre, Land Registry, and Mapping Agency (Kadaster). For buildings the BAG provides 2D geometries and some basic attributes such as identification number, year of construction, purpose of use, total number of building units in a building and status of the building. However, information on the height of buildings and building units, the number of floors in a building, and the number of condominium (dwelling) units per floor are not included in the register. The BAG, on the other hand, provides some information on residence (dwelling) units as well, such as floor area size of residence unit, status, purpose of use, address information (street name, house number, house letter, postal code, name of public space, name of residence area) and reference to the information on the building in which the residence unit is situated (year of construction, building status, building ID). The residence units are geometrically represented as points in 2D.

For 3D visualisation of residence units (apartment/condominium) in multi-occupied buildings, the boundaries of the condominium units and the common spaces, the total number of floors and the height of each floor in a building are required. Although this is not considered as a sustainable approach, the total number of floors was determined from the photographs of the buildings. Each adjoined part of the multi-occupied buildings has 11 floors (including the ground floor) as can be seen in Fig. 5. The total number of residence units in each building block is given in the total residence unit number attribute of BAG as 20 (the points on each of the footprints of the building blocks in Fig. 6 represent a residential unit). Therefore, it is interpreted that the ground floor is allocated for common use and each of the 10 floors has two residence units. In addition, the difference between the total area size of residence units on a floor and the footprint area of the buildings (which was measured using BAG data) is taken as the area of common spaces on each floor above the ground floor. It is considered that the locations of the points representing the residence units in the BAG and WOZ registers corresponds to the situation in reality. The orientation of the residence units (facing direction) was determined on the basis of this assumption. The attributes shown in Fig. 5 are: unique building identifier (Identificatie), minimum and maximum size of the residence units (oppervlakte_max and oppervlakte_min), linked data representation of the building (rdf_see also) and status of the building, which in this case is 'building in use' (pand in gebruik).

The estimated legal spaces of the valuation units can be identified with the developed prototype. Moreover, it is possible to distinguish the estimated private and common parts of the selected multi-occupied buildings. With the inferences and assumptions made, the footprints of the residence units and common spaces for one floor are estimated and drawn in 2D space (Fig. 7) to be extruded for 3D visualisation afterwards.

The heights of the multi-occupied buildings were obtained from the 3D BAG[18] dataset, which is another open data platform aiming to represent BAG buildings in 3D in different LoDs, using the national height data AHN.[19] In LoD 2.2 (see previous section), the average height of the multi-occupied buildings is 31 m. Therefore, it is assumed that each floor has a height of 2.82 m (including floor thickness) and the estimated boundaries of residence units are extruded accordingly with 2.82 m for each floor in order to obtain legal spaces of the units. It is important to note that the thickness of the floor is considered to belong to the private space, not the common space in the multi-occupied buildings of this prototype. The height and the shape of the selected single-family buildings are consumed directly from the 3D BAG dataset in LoD 2.2.

Fig. 8 shows the specified levels for the aggregation of valuation units into valuation unit groups. Within the scope of this study, only four designated levels (i.e., condominium, floor, building and street) are implemented. For each level implemented, a separate 3D tile is created to facilitate management and possible future updates. The developed prototype is available online.[20]

The assessed values (WOZ-value) of each residence unit (WOZ-object) between 2014 and 2020 were obtained from the WOZ register. Fig. 9 shows how the selected valuation units can be viewed in the current WOZ register (WOZ-waardeloket) on the Web.

The WOZ-objects and residence units are linked by the address attributes. The prototype presented in this study allows the user to query the values for each condominium unit in a selected year, see Fig. 10. When a condominium unit is selected, the valuation information associated with the unit (coloured in red) appears as a table on the right-hand side of the screen in Fig. 10. The grey coloured spaces represent the estimated common parts in the buildings.

In the floor level implementation, any floor in multi-occupied buildings can be selected. Fig. 11 shows the legal space of the tenth floor of the selected building and its attributes. The floor level implementation can be improved with some additional queries such as, information on the floor level of buildings in a street and/or neighbourhood.

The building footprint obtained from BAG is extruded by an average of 31.1 m (calculated considering 3D BAG and AHN datasets) for multi-occupied buildings. The average value for residence units and the average value per square metre for each building in each year is calculated using the existing residence unit values. The building level implementation for the multi-occupied building is shown in Fig. 12.

Fig. 13 shows the implementation of the prototype for single-family buildings/houses. It should be noted that some of the selected single-family buildings have car parking spaces which are automatically highlighted when the corresponding building is selected, see red coloured house and car parking space in Fig. 13. In the prototype the individual WOZ-objects and WOZ-values for the single-family houses are implemented in the view on level 3 and not on level 1. It should be noted that this choice has been made because there is only one WOZ-object within the building, but perhaps for the general user of the system, it would be practical to make it possible to select the individual single-family properties also on level 1 in future developments.

In the street level implementation (Fig. 14), the valuation units are grouped in street level. When a selection is made, all the valuation units

[18] https://3dbag.nl/

[19] Digital Elevation Model data for the Netherlands (AHN), see https://www.ahn.nl/

[20] https://nlvaluation.landadmin.org/

Fig. 6. BAG data of the building blocks and residence units (the points on each of the footprints of the building blocks represent a residential unit).

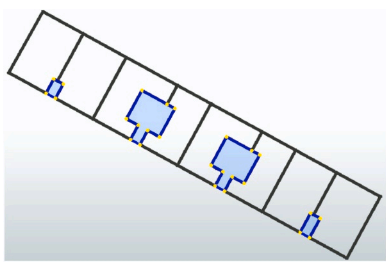

Fig. 7. Estimated boundaries of residence units and common spaces in buildings.

that have the same function (i.e., residential) are highlighted and the statistical information derived from these valuation units (i.e., average value of the valuation units, average value per square metre, annual increase in value, min/max year of construction) is displayed.

5. Conclusions

This paper focuses on unfolding the situation why some countries require a property valuation model different than the cadastre and land registry, and then on the visualisation and dissemination of valuation information associated with 3D valuation units and groups. The prototype is based on a proposed classification for aggregating valuation units into groups of valuation units and is developed using open datasets with some assumptions.

Property values should be recorded not only to support land administration processes efficiently, but also to manage and disseminate values transparently. As valuation units are not always the same as cadastral registration units, a valuation register is required in many countries, including the Netherlands. The assessment of changes in value, the recording of information on individual and mass valuation procedures and the handling of appeals are also reasons why a specific register for valuation information is necessary. LADM_VM can be used to support all these aspects. By extending the LADM_VM, country-specific characteristics for valuation processes can be represented by a country profile, which is then used to derive an application schema for managing the valuation information and also as a basis for visualisation and dissemination of the information.

The development of a web-based system for the dissemination of valuation information is a challenging task. To accomplish this task, the problem defined in this paper is broken down into small steps. In the first step, the requirements and possibilities for developing a web-based 3D visualisation and dissemination prototype for property valuation information are investigated, taking into account the experience gained from studies that developed a 3D cadastral visualisation prototype. In this step, a classification is also proposed for the aggregation of valuation units into groups that can make the dissemination more efficient and effective. Subsequently, considering the specified requirements, an

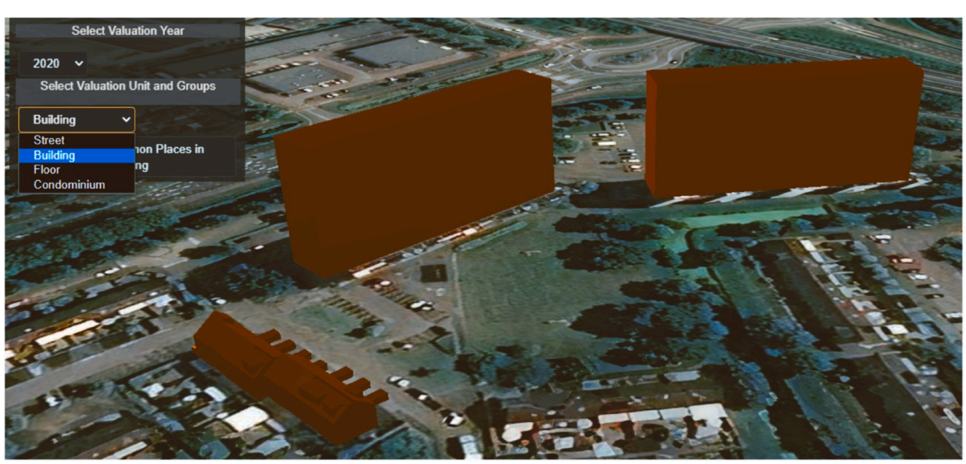

Fig. 8. Specified levels for visualisation of valuation information.

Fig. 9. WOZ register view of the selected single- and multi-family buildings.

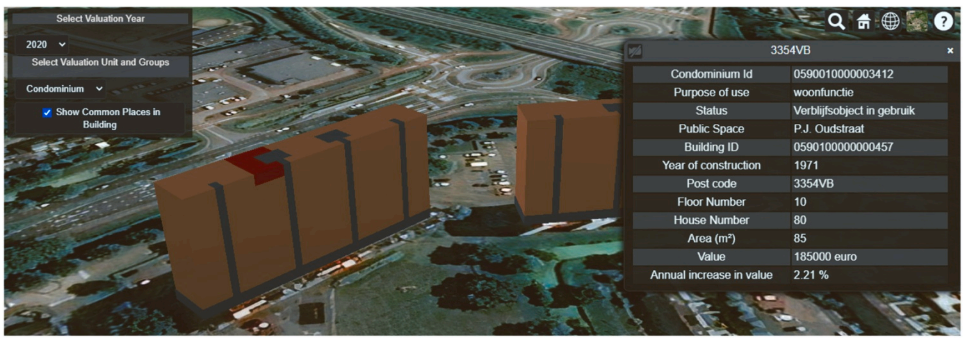

Fig. 10. Single (residence) unit implementation of the prototype.

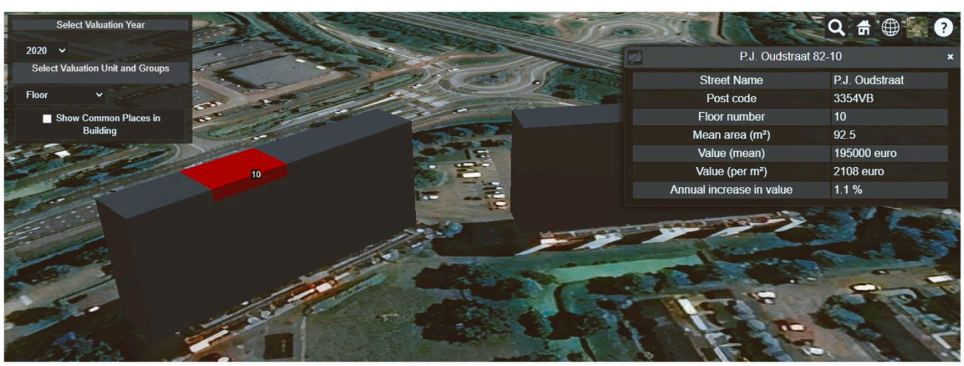

Fig. 11. Floor level implementation of the prototype.

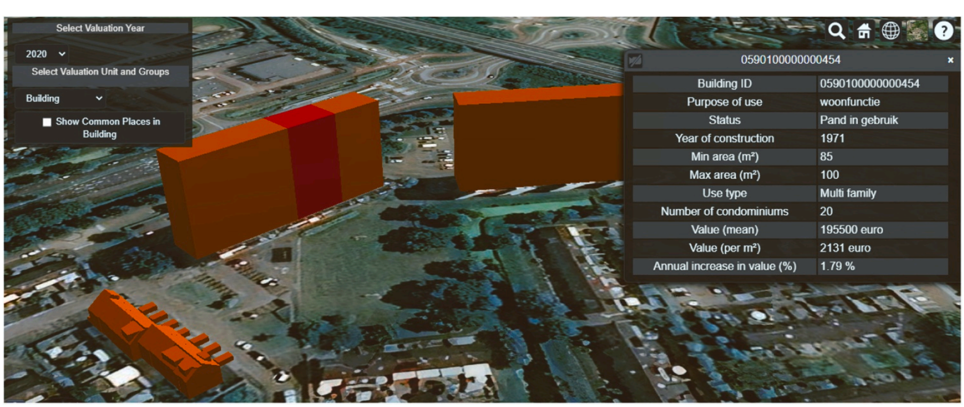

Fig. 12. Building level implementation for the multi-occupied building.

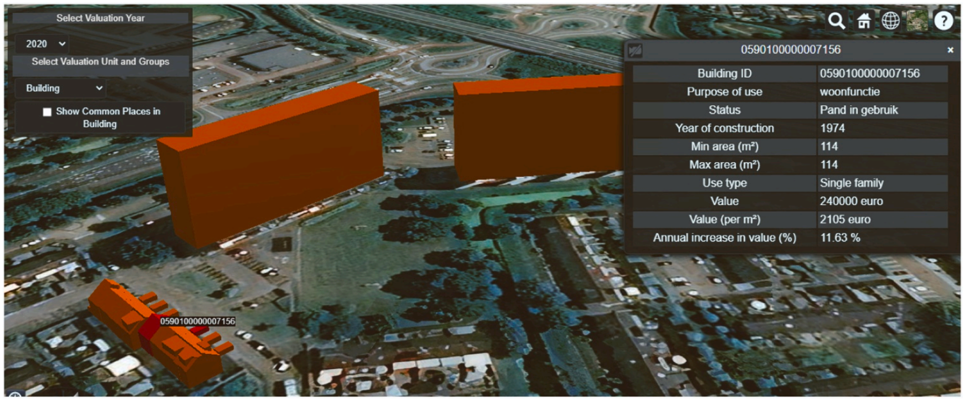

Fig. 13. Building level implementation for the single-family building.

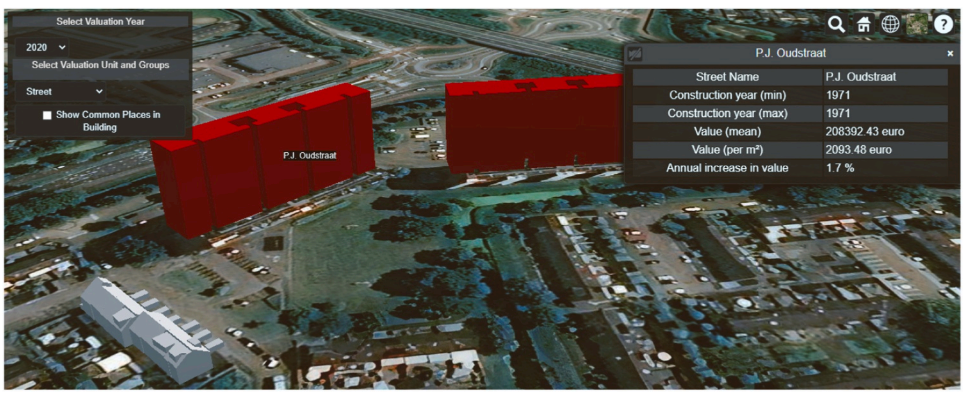

Fig. 14. Street level implementation of the prototype.

initial prototype system for the dissemination of valuation information through 3D single valuation units (e.g., condominium) and valuation unit groups (e.g., building floor, building and street) for the Netherlands is developed and presented.

During the development of the prototype, several challenges were encountered, one of which is the creation/derivation of 3D valuation units. Creating 3D models for single-family dwellings is relatively easy compared to multi-family dwelling (multi-occupied building). However, it is important to create the 3D models for multi-family dwellings as well, as the 3D location provides additional information especially for these types of dwellings. A 3D model for multi-family dwellings requires the division of space into individual and common areas, and this is a difficult task without floor plans or BIM/city models, which today cannot be used as a basis for visualising 3D valuation units (with distinguishable individual and common areas) in a neighbourhood, as BIM/city models, for example, are not available for buildings built in the 1970s. Furthermore, it should be noted that 4D cadastral models (Van Oosterom et al., 2006) can also be a crucial data source for the development of efficient prototype systems for the dissemination of valuation information, as these models focus more on temporal aspects and buildings are likely to be more dynamic than legal land units (parcels), especially in urban areas, not only because of new constructions but also because it may be expected that transformation from single-family houses to multi-occupancy buildings will arise in the near future due to the population growth and the rapid increases in property prices.

Some assumptions are made in this paper in relation to visualisation of e apartment buildings in 3D. The assumption, for example, made for determining the number of floors in buildings is not sustainable. A robust methodology should be followed to determine the total number of floors in multi-family buildings, similar to Roy et al. (2022), in order to take a further step towards fully automating the prototype development process, which is one of the authors' future goals. Another future goal is to enrich the prototype with some additional functionality (e.g., integrating animations and graphics into the prototype to show value changes for valuation units and groups), and with more building types (e.g., corner house). When developing the prototype, half of the effort is spent on data collection. Therefore, the planned collaboration with the municipality of Papendrecht and the organisation Drechtsteden may speed up the prototype development process.

One of the future works is to test the 3D models of the valuation units (e.g., location, orientation, etc.) may be by adding a questionnaire to the prototype for the owner of the valuation unit. The authors plan to extend the scope of this study with a research proposal. In the first instance, the authors would like to implement the proposed level structure at a municipal level, and then perhaps at a national level. Depending on the results of the proposed research, and pilots for larger areas, in the future this functionality could be added to the current national portal for valuation information, which is today limed to 2D representations and not very clear for multi-floor apartment complexes. Furthermore, developing a suitable tileset creation methodology to make this prototype available throughout a district or municipality can also be considered as a future work activity in the context of developing a new coherent registration (SOR) in the Netherlands. The development of the SOR can also speed up the development of the 3D dissemination of property values in the Netherlands because more information on property characteristics and 3D representation of this information will become available.

The following questions are also identified for further research (a) is privacy an issue in disseminating valuation information associated with 3D visualised valuation units (e.g., an apartment), more than visualising the value on a 2D map? (b) how can the possible value of airspace or underground areas be included in such a prototype?

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data used in this paper is open to the general public on the Web.

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