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Key words: 3D Cadastre, Property valuation, LADM Valuation Information Model, ISO 19152:2012 Land Administration Domain Model (LADM), 3D GIS, 3D geospatial analysis

SUMMARY

Property valuation is a process of estimating value of an immovable property. The legal, geometric, physical and environmental characteristics of the immovable property together with the economic indicators are taken into consideration during this process. Traditional cadastral systems only provide two-dimensional (2D) legal and geometric information about property units. However, today's complex valuation practices (e.g. computer aided mass appraisal) would benefit significantly from three dimensional (3D) information on not only property units but also their physical counterparts (e.g. buildings, building parts). Moreover, 2D and 3D environmental information is needed for determining environmental conditions about immovable properties to better estimate the values of them.

A collaborative research initiative has proposed an international valuation information model that extends the LADM for specifying semantics of valuation registries maintained by public authorities. The current version of the LADM Valuation Information Model, however, does not include detailed specification for the environmental characteristics of immovable properties (e.g. presence of views, level of visibility and distance to amenities) which can be derived with 2D and 3D geospatial analyses by means of various data sources.

The purpose of this paper is to examine which geospatial analyses, especially 3D analyses, can be used to provide information about immovable properties including environmental and locational characteristics for property valuation activities. Furthermore, it is investigated that how property valuation can benefit from data sources including semantically rich 3D building, city and cadastral models for deriving environmental and locational characteristics of property units. To achieve these objectives, the data sources and geospatial analyses are initially investigated in the context of property valuation. Then, the paper focuses more on viewshed analysis. By using open topography, building and height datasets of the Netherlands and 3D GIS analysis, a viewshed analysis is presented to show how it can be utilized using different data sources for better understanding and explanation of values of the properties. The paper is concluded with a discussion to what extent it is possible and meaningful to include (derived) environmental characteristics of properties in the LADM Valuation Information Model.

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1. INTRODUCTION

Property valuation is a process of estimating value of an immovable property at a particular moment of time (Millington, 2013, p. 53). Traditional cadastral systems provide geographical and legal datasets concerning the legal objects required for property valuation, however, cadastral datasets used for identification and registration of legal interest in relation to immovable properties may not be sufficient for today's complex valuation practices. For example, mass valuation, which is *en masse* valuation of groups of properties for the same purpose such as immovable property taxation, price indices construction and understanding market dynamics, relies on detailed information about immovable properties (Almy, 2014, p. 14; Jahanshiri et al., 2011). In other words, the traditional cadastral systems only provide two-dimensional (2D) geometry and legal information about immovable properties, whereas valuation practices also require three-dimensional (3D) geometrical (Işıkdağ et al, 2014; Işıkdağ et al., 2015), physical (e.g. building units area, building age), fiscal (e.g. transaction price, rental price), and environmental (e.g. view, distance to amenities) data to better estimate values of immovable properties (Çağdaş et al., 2016, Kara et al., 2018).

ISO 19152:2012 Land Administration Domain Model (LADM) is an international standard for the domain of land administration that is related to management of information concerning the ownership, value and use of land. It focuses on legal and administrative aspects of land administration and considers out of scope of the value component. Moreover, the ISO 19152:2012 only provides information on legal spaces of building parts, however, physical spaces and characteristics of building parts are also utilized in property valuation activities. Nonetheless, it provides a formalism that allows for an extension that responds to property valuation requirements.

A recent initiative, which is supported by International Federation of Surveyors (FIG) Commission 9 (Valuation and the Management of Real Estate) and FIG Commission 7 (Cadastre and Land Management), has developed an information model with extending the scope of LADM for specifying the semantics of immovable property valuation inventories maintained by public authorities. It provides a conceptual schema for the data concerning valuation units that are objects of valuation (e.g. cadastral parcels, buildings and condominiums), parties involved in the valuation practices, transaction prices and sales statistics. The proposed LADM Valuation Information Model provides detailed information on the legal, geometric, physical characteristics of the valuation units. It links semantics and physical spaces of valuation units with their legal counterparts defined in LADM since the property valuation requires detailed information on physical characteristics of valuation units (e.g. floor area and age). On the other hand, the current version of the LADM Valuation Information Model does not include detailed semantic information for the environmental characteristics of valuation units (e.g. presence of views, level of visibility and distance to amenities), which can be derived with 2D and 3D geospatial analysis by means of various data sources.

The purpose of this paper is to examine which 2D and 3D geospatial analyses can be used to provide information about immovable properties including environmental and locational characteristics for property valuation activities. It is also researched to what extent it is possible and meaningful to include (derived) environmental characteristics of properties in the LADM Valuation Information Model. The following section briefly describes general structure of the LADM Valuation Information Model. Section 3 investigates that how property valuation can benefit from data sources including semantically rich 3D building, city and cadastral models for deriving environmental characteristics of property units. This section also examines geospatial analyses that can be used to derive information about environmental and locational characteristics of immovable properties for property valuation activities. These analyses include visibility analysis, solar potential analysis, flooding risk analysis, noise analysis, distance analysis (routing to key facilities: shops, schools, parks, sports, public transport, hospital, etc.), daylight and sunlight analyses. It is noted that this section focuses more on the viewshed analyses in the context of property valuation. In section 4, by using open topography, building and height datasets of the Netherlands, a viewshed analysis is presented to show how it can be utilized for better understanding and explanation of values of property units. The view contents of viewshed areas, of properties, for example, is specified in order to provide data for valuation activities. The paper is concluded with a discussion whether the environmental characteristics of property units can be included in the conceptual schema of LADM Valuation Information Model and future works.

2. LADM VALUATION INFORMATION MODEL

This section provides a brief overview of LADM Valuation Information Model. Figure 1 represents an overview of LADM and LADM based Valuation Information Model. While the classes with white color and LA_ prefix represents LADM, the classes with vanilla color and VM_ prefix represents the Valuation Information Model.

The purpose of LADM Valuation Information Model is to specify semantics of inventories utilized in immovable property valuation and relations between them. It is supposed that LADM Valuation Information Model will provide public bodies a common basis for the development of local or national inventories, enable integration of valuation inventories with cadastral system, and may act as a guide for the private sector to develop information technology products.

Cadastral systems generally provide 2D legal situations of properties; however, locational and physical characteristics of valuation units are also needed in valuation activities. Furthermore, geospatial analyses, which may be used to derive additional characteristics about valuation unit, need the physical spaces of valuation units. Since the focus of this paper is geospatial analysis and environmental characteristics of valuation units, this section only gives information about physical (spatial) part of the LADM Valuation Information Model (objects of valuation). It is noted that more detailed information about the model is presented in Çağdaş et al. (2016) and Kara et al. (2017, 2018).

The basic registration unit of cadastral systems (e.g. a cadastral parcel) may differ from the basic units of valuation systems (e.g. a building) in both 2D and 3D (Çağdaş et al., 2016). Therefore, the class named VM_ValuationUnit is created in order to represent the basic recording unit of valuation inventories. It has the characteristic named valuation unit type, which specifies possible valuation unit (e.g. only parcels, or only buildings, or parcels and buildings together, or condominiums). VM_ValuationUnit also includes neighborhood type characteristic is used to denote the type of neighborhood where the valuation unit is located (e.g., urban, rural), and the utility services characteristic record the available utility services (e.g., natural gas, electricity). The spatial and physical characteristics of the valuation units are detailed with VM_SpatialUnit, VM_AbstractBuilding, VM_CondominiumUnit classes that have relations with the VM_ValuationUnit.

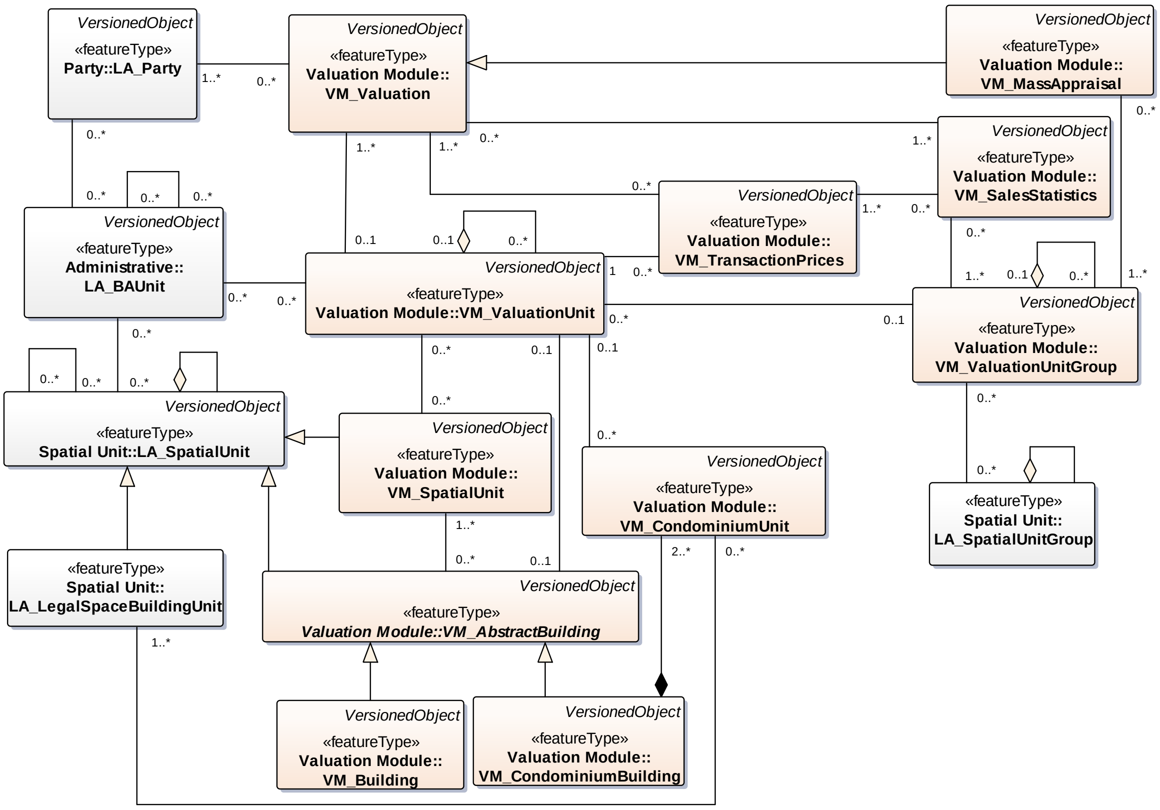

Figure 1. An overview of LADM Valuation Information Model

VM_SpatialUnit class represents cadastral parcels, as well as sub-parcels in valuation inventories. It is defined as child class of LA_SpatialUnit that supports 2D, 3D or mixes representation of spatial units (ISO 19152:2012). VM_SpatialUnit has characteristics for current and future land use. The Hierarchical INSPIRE Land Use Classification System (HILUCS) provides a code list for both existing and planned land use (Kara et al., 2018)

LADM is only concerned with the legal space of buildings and building parts (e.g., individually owned apartments, jointly owned building parts), which does not necessarily coincide with the physical space of a building (ISO 19152:2012, p. 11). VM_AbstractBuilding, is the child class of LA_SpatialUnit, specifies physical characteristics of buildings and building parts. It provides a set of common characteristics shared by its sub-classes, such as type of use and building type.

VM_AbstractBuilding has two concrete classes, VM_Building and VM_CondominiumBuilding. The former represents buildings that are considered as complementary parts of parcels, but may be valued separately from the parcels on which they are located. The latter, VM_CondominiumBuilding, is adopted from the OGCs LandInfra standard to specify buildings that contain condominium units established according to condominium schemes (OGC, 2016). It is also noted that the OGCs LandInfra standard found inspiration from Çağdaş (2013) when developing the condominium schema. A condominium building consists of (i) condominium units (e.g. flats, shops); (ii) accessory parts assigned for exclusive use (e.g. garages, storage areas); (iii) and joint facilities covering parcel, structural components (e.g. foundations, roofs), accession areas (e.g. entrance halls, spaces), and other remaining areas of buildings (e.g. staircases, heating rooms) (Kara et. al., 2018). The LADM Valuation Information Model proposes a VM_CondominiumUnit class to record the main physical condominium unit characteristics, such as floor area, related accessory parts and shares in joint facilities. It is noted that the floor area terms defined in the ISO Performance Standards in Building (ISO 9836:2017) are adopted in model.

Lastly, it is noted that valuation unit may be grouped according to zones (e.g. administrative divisions, market zones) that have similar environmental and economic characteristics, or according to types of valuation units (e.g., commercial, residential, agricultural) that have similar physical characteristics in mass valuation. This issue is addressed by the VM_ValuationUnitGroup class in the Valuation Information Model.

The proposed LADM Valuation Model does not include detailed information on environmental and locational characteristics of the valuation units. Next section investigates the data sources and geospatial analyses in terms of deriving information, especially environmental information, for property valuation activities.

3. DATA SOURCES AND GEOSPATIAL ANALYSES FOR VALUATION

A wide variety of immovable property characteristics is used in valuation activities. Sirmans et al. (2005) investigated the mostly used characteristics that have been used to specify a valuation model. According to the study, building age, floor area of building parts and lot size are the mostly used characteristics. This study also determines the mostly used environmental and locational characteristics of valuation units, which are view (e.g. lake, ocean, golf and mountain view), distance between two points (e.g. central business district, metro station, busy road, beach, waste, school and landfill), noise (e.g. airport and neighborhood noise), crime, golf course and tree. It can be emphasized that utilized environmental and locational characteristics of valuation units may differ one valuation model to the another according to purpose of valuation, valuation zone, type of valuation unit, decision of valuer and so on. For example, Brasington and Hite (2005) presented a valuation model to estimate the relationship between house prices and environmental quality and used distance to hazard as a variable. Moreover, Poudyal et al. (2009) searched the demand of parks in the United States and used distance to park as a variable.

The valuation unit characteristics including environmental and locational characteristics can be derived from semantically rich 3D building, 3D city and cadastral models together with geospatial analyses. In addition to these, street view, cyclorama, satellite imagery and laser scanning may also be utilized to derive data for property valuation activities. These data sources can be used for variety of different purposes in valuation. For example, aerial photographs and street view type of images (cyclorama's) are utilized to derive valuation unit characteristics such as type of building or grade for maintenance condition in the Netherlands (Işıkdağ et al., 2014). Furthermore, 2D city models and web mapping services can be employed to determine distance between two points such as distance to park and distance to beach.

In recent years, 3D datasets are widely used to provide information for valuation activities. One of the main application with the 3D datasets is to estimate size of floor areas in buildings and building parts (Biljecki et al., 2015). For example, floor area with the ceiling height lower than 1.5 meter is not taken into the area computation according to the NEN 2580:2007. In this context, Boeters (2013) has automatically enhanced CityGML LoD2 model with interiors and has used it to compute net internal area defined in the NEN 2580:2007. Besides this, there are many usages of 3D datasets with geospatial analysis to produce data for property valuation. One of them is noise analysis at a location of a house, however, it is noted that such an analysis have not been documented yet (Biljecki et al., 2015). On the other hand, some studies investigate the relation between house prices and noise. For example, Cohen and Coughlin (2008) investigated the airport noise effect on house prices and Wilhelmsson (2000) searched the impact of traffic noise on the values of single-family houses. Both of the studies have found out that the noise has a negative effect on value. Moreover, 3D hazard analyses may also be used in property valuation. The authors did not find such a study in the literature but it is noted that Ghanbarpour et al. (2014) used 2D data to reveal the relation between floodplain inundation analysis and valuation. 3D datasets are also used for crime analysis in recent years (Wolff and Asche, 2009). Crime is usually measured as the crime rate for a given area and typically has a negative effect on price (Sirmans et al., 2005). Furthermore, estimation of the insolation of buildings such as sunlight and daylight analyses has been used in property valuation. For instance, Helbich et al. (2013) utilized insolation as a variable in the valuation model and suggested that solar radiation is significantly capitalized in property prices. On the other hand, applications and analysis of 3D datasets may also provide additional data for property valuation. For example, Henn et al. (2012) presented a method to detect the type of a building with 3D geometry that may be used in property valuation activities since the type of building is an important factor to estimate values of properties.

Apart from the above-mentioned geospatial analyses, it may be stated that the 3D view analyses are one of the most important 3D analysis for valuation activities. This argument can be supported with the study of Sirmans et al. (2005) as it found out that view of valuation units is the mostly used environmental characteristics in valuation. There are a number of visibility analyses such as line of sight, volume of sight, sky view factor, visibility of landmark and viewshed. Literature review shows that the mostly used visibility analysis in valuation domain is viewshed analysis. In addition, a few studies used visibility of landmark analysis. For example, Moon (2010) identified landmark factors that affect the price of super high-rise residential buildings.

A viewshed is an area that is visible from a specific location. A number of different usages of viewshed analysis has been found in the literature. For example, Hamilton and Morgan (2010) estimated how access and view factors of urban beach residential properties affect the values. The results of the study indicated that a property's view is a significant component of a properties' value. Another study utilized the viewshed analysis to measure the impact of man-made lake views on urban residential properties (Schmitz, 2008). The result of the study indicates that the lake view increase values of property units between 7.5% and 8.3%. Moreover, Tomić et al. (2012) used 3D vector terrain model created from the digital cadastral maps for viewshed areas of condominiums. The results of the study is based on the assumption that a property with a bigger visibility polygon, i.e. a better view, has a bigger market value than the same real estate with a smaller visibility polygon. These studies utilized viewshed analysis to indicate whether there is a view of a certain amenity. On the other hand, some studies utilized visibility analysis for specifying types or content of view of properties. For example, Hindsley et al. (2013) construct four continuous measures of Gulf of Mexico views, i.e. the total view, the maximum view segment, the mean view segment, and proximity to view content. The result of the study illustrates that residential property owners have a higher marginal willingness-to-pay for larger total views and larger continuous view segments. Moreover, Paterson and Boyle (2002) compared the visibility of land use of properties with four types of land use types, i.e. development, agriculture, forests and surface water. This study shows that values of properties are positively correlated with the presence of forests. Lastly, Oud (2017) used open LIDAR and building data of the Netherlands to calculate viewshed polygons. Then the viewshed polygons and open land use data of the Netherlands were overlaid to determine visibility of land use types such as traffic, water, green and development. The valuation results shows that the view of a property is significantly improving the model and has an impact on the value of the property.

The viewshed analysis requires observer(s) and obstacle datasets. Most of the examined studies above considered observers as point(s). In some cases, this approach may create drawbacks to represent view of a property unit and usage of observer line(s) may provide more accurate viewshed polygon of a property. Furthermore, they were used different datasets and approaches to represent obstacle(s) in viewshed analysis. For example, Oud (2017) used both only 3D buildings and 3D buildings with surface (digital surface model) as obstacles to calculate viewshed area of a property.

Next section presents a viewshed analysis to illustrate how it can be used in property valuation using different datasets.

4. VIEWSHED ANALYSIS WITH OPEN DATASETS OF THE NETHERLANDS

This section investigates how viewshed analysis can be applied utilizing different data sources and models (approaches). The methodology used in Oud (2017) is followed to determine visibility of land use types of buildings with some differences. For example, observers are considered as line(s) in this study. Moreover, viewshed areas are determined using three different obstacle datasets. It is noted that both studies used an automated approach to determined viewshed areas of properties.

In this study, open datasets of the Netherlands, namely datasets from BAG (the Basic Registration Addresses and Buildings), TOP10NL (1:10000 digital topographical base map of the Netherlands), AHN3 (point cloud dataset) and some combination of them are used to make viewshed analysis. A small area with eight buildings in Alkmaar, the Netherlands is chosen as study area (see Figure 2). Viewshed2 tool of ESRI ArcGIS commercial software is used for the analysis. The viewshed tool requires point(s) or line(s) as observers and an elevation dataset in raster format that represents the obstacles blocking the view. The output is a raster file that represents the view/visible area of the observer(s).

The observers in this study are derived from building footprints, which are provided by BAG and TOP10NL by converting them to polylines. The elevation of the observers were calculated through building elevations, simply by subtracting an offset value from them. BAG provides the footprints of the buildings without height characteristics, while, TOP10NL provides building footprints with heights. The point cloud dataset (AHN3) was utilized in order to determine the heights of the BAG buildings. The mean of height values of points on each building footprint was calculated using summary statistics tool in ArcGIS. Then, the calculated height values were assigned as elevations to the buildings.

Figure 2 shows the selected study area and the observer buildings. The characteristics of the selected observer buildings such as footprint area, building ID and height are presented in Table 1. It should be highlighted that the selected eight buildings from BAG corresponds to two buildings from TOP10NL because of the data generalization.

After the observer lines were specified, the obstacle datasets were constructed with three different models (approaches). In 'Model 1', a Digital Surface Model (DSM) was produced using AHN3 first return of point cloud data. The ground level points of AHN3 point cloud were filtered to produce Digital Terrain Model (DTM) in 'Model 2'. In this model, building footprints were obtained from BAG registers and extruded with mean height values that were derived from AHN3 point cloud using summary statistics. Then, it was converted to raster. In other words, DTM and 3D buildings together were taken into account as obstacles in 'Model 2'. Lastly, TOP10NL dataset was used to construct another obstacle dataset for 'Model 3'. 2.5D terrain, buildings, water, bridges and roads in the TOP10NL were firstly merged and then converted to raster with 25 cm resolution. The converted dataset represents obstacles in 'Model 3'. Figure 3, Figure 4 and Figure 5 represents the 'Model 1', 'Model 2' and 'Model 3', respectively.

Figure 2. Study area and the characteristics of observer buildings

Table 1. Characteristics of the seleceted observer buildings

BAG			TOP10NL		
Building ID	**Footprint Area**	**Height**	**Building ID**	**Footprint Area**	**Height**
2	69.56	6.18	9	300.69	5.81
3	72.14	5.95			
6	70.17	6.71			
7	72.12	6.01			
1	72.12	5.94	10	297.14	5.83
4	70.17	6.02			
5	69.56	6.01			
8	72.12	5.81			

As stated before the methodology defined in the Paterson & Boyle (2002) and Oud (2017) is followed in terms of determining view contents of the viewshed area. In this study, open land use dataset (BBG) and the viewshed polygons were overlaid. Then, the intersection areas were used to determine view content of the observers. Figure 6 depicts the land use types in study area.

Figure 3. ’Model 1’ digital surface model prodoced with first return points of AHN3

Figure 4. ’Model 2’ digital terrain model produced with ground level points of AHN3

Figure 5. ’Model 3’ TOP10NL dataset

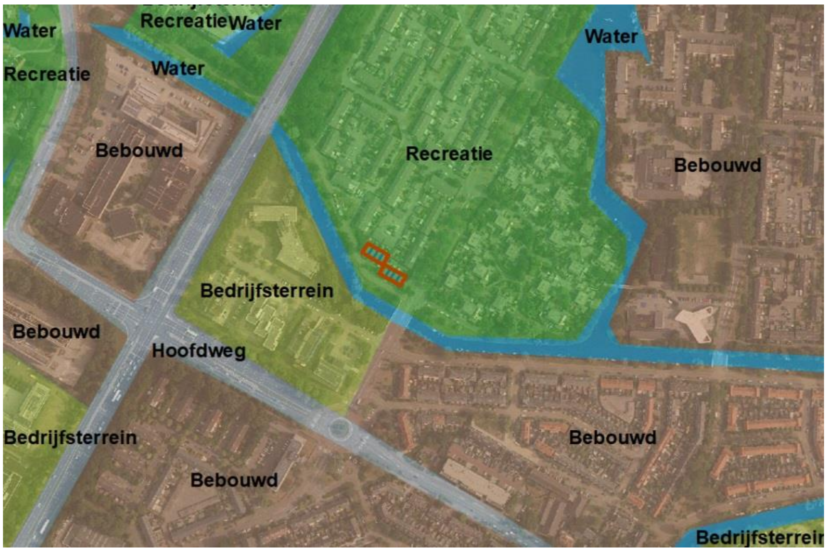

Figure 6. Land use types in the study area (Bebouwd: cropped, Bedrijfsterrein: installation, Hoofdweg: highway, Recreatie: recreation, Water: water)

Figure 7 shows the workflows for viewshed analysis with different data sources and models. The blue blocks represents input datasets, while vanilla blocks shows intermediate layers. Moreover, dark red blocks represents obstacle datasets and green blocks shows output datasets. Pink dashed lines represent workflow for Model 1 and green dotted lines represent workflow for Model 3.

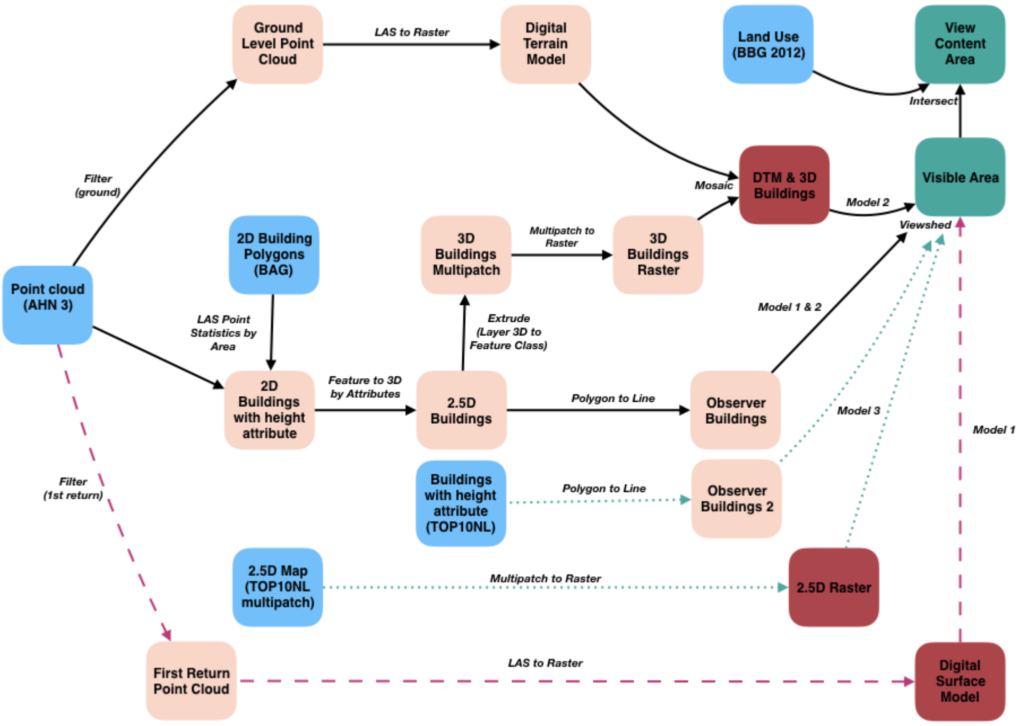

Figure 7. Workflows for viewshed analysis with different data sources and models

In order to automate the determination of visible area and view contents for multiple observer buildings, a tool was generated using ArcGIS model builder (see Figure 8).

There are two input layers in viewshed analysis. The observer lines were derived from the observer buildings and obstacle raster datasets were produced via ‘Model 1’, ‘Model 2’ and ‘Model 3’. Input parameters are observer elevation, observer offset and outer radius in viewshed analysis. Observer elevation indicates the absolute height of the observer line, while the observer offset is a parameter added to the observer line. Outer radius defines the extent of the visible area. In this study, height of the buildings were taken into account as observer elevations, which were calculated from point cloud dataset for ‘Model 1’ and ‘Model 2’. The elevation data provided by TOP10NL dataset was directly used for ‘Model 3’. With the assumption of the average height of a floor in a building is 3 meters, observer offset was set to -1.3 meters representing a person with an average height in the last floor of a building. The outer radius was set to 250 meters since Cavailhès et al. (2009) stated that only a few attributes remain significant up to 150–300 m radius.

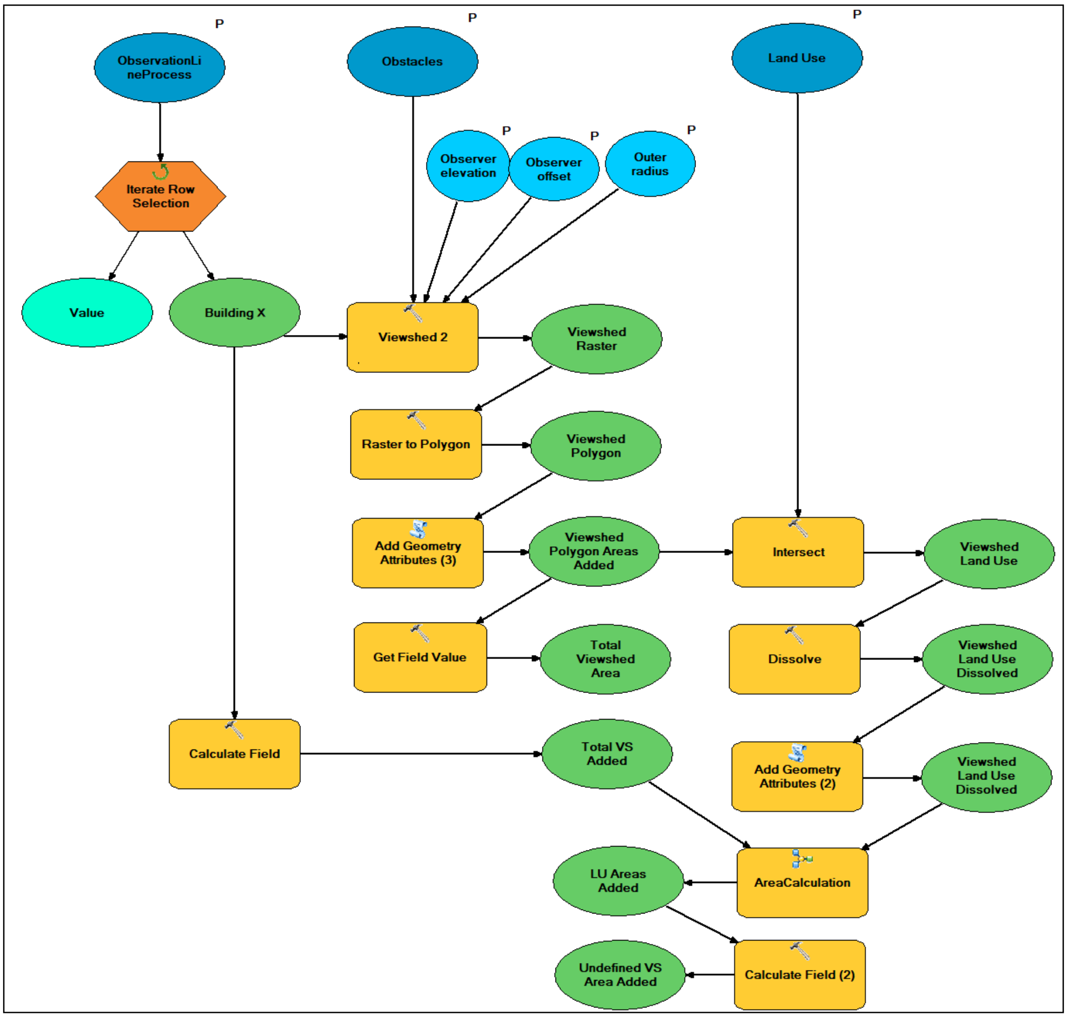

Figure 8. Tool for automating viewshed analysis for multiple observer lines

Figure 9 and Table 2 shows the total visible area determined through ‘Model 1’ and ‘Model 2’, i.e. DSM and DTM+3D buildings. he red areas presents the visible areas determined by ’Model 1’, while green areas presents the visible areas determined by ’Model 2’. The analysis indicates a significant difference between total view areas for the same building determined by using two models. Since the DSM contains tree canopies and building roofs, and ‘Model 2’ uses LOD2 buildings and no trees and vegetation, the visible areas of the building determined with ‘Model 1’ are smaller compared to with ‘Model 2’.

Figure 9. Comparison of visible area with ’Model 1’ and ’Model 2’

Table 2. Comparison of visible areas with ’Model 1’ and ’Model 2’

Total Visible Area		
Building ID	**Model 1**	**Model 2**
1	5728.44	31807.88
2	4749.19	17948.75
3	4465.13	24269.75
4	4777.56	22549.31
5	4242.44	24315.13
6	5446.13	20949.25
7	4128.31	17216.06
8	4858.31	23886.00

In order to compare 'Model 2' and 'Model 3' on a consistent base, union of viewshed polygons of BAG buildings, which correspond to buildings in TOP10NL dataset (Building 9 and 10), were formed. The view contents and areas of these viewshed polygons are shown in the Table 3. While the total visible area and contents determined with 'Model 2' are significantly larger than with 'Model 3' for both observer buildings, the percentage of the view contents are very similar. This indicates that TOP10NL is suitable for viewshed analysis in particular for large buildings. In other words, the large buildings that do not need to be generalized in small-scale maps, such as 1:10000, TOP10NL buildings may be more suitable for viewshed analysis in property valuation. Figure 10 presents the percentage of view contents of viewshed polygons for 'Model 2' and 'Model 3'.

Table 3. Comparison of visible land use type areas with 'Model '2' and 'Model 3' (Bebouwd: cropped, Bedrijfsterrein: installation, Hoofdweg: highway, Recreatie: recreation, Water: water)

	Building 9			Building 10	
Land Use	**Model 2**	**Model 3**		**Model 2**	**Model 3**
Hoofdweg	2287.3	1427.8		3036.2	2152.4
Bebouwd	14948.2	10850.5		9002.7	7221.9
Bedrijfsterrein	9885.2	7715.6		9850.9	7738.0
Recreatie	18792.1	13575.9		10044.8	8842.6
Water	4633.4	3781.1		4263.1	3804.1
Total	50546.3	37350.8		36197.6	29758.9

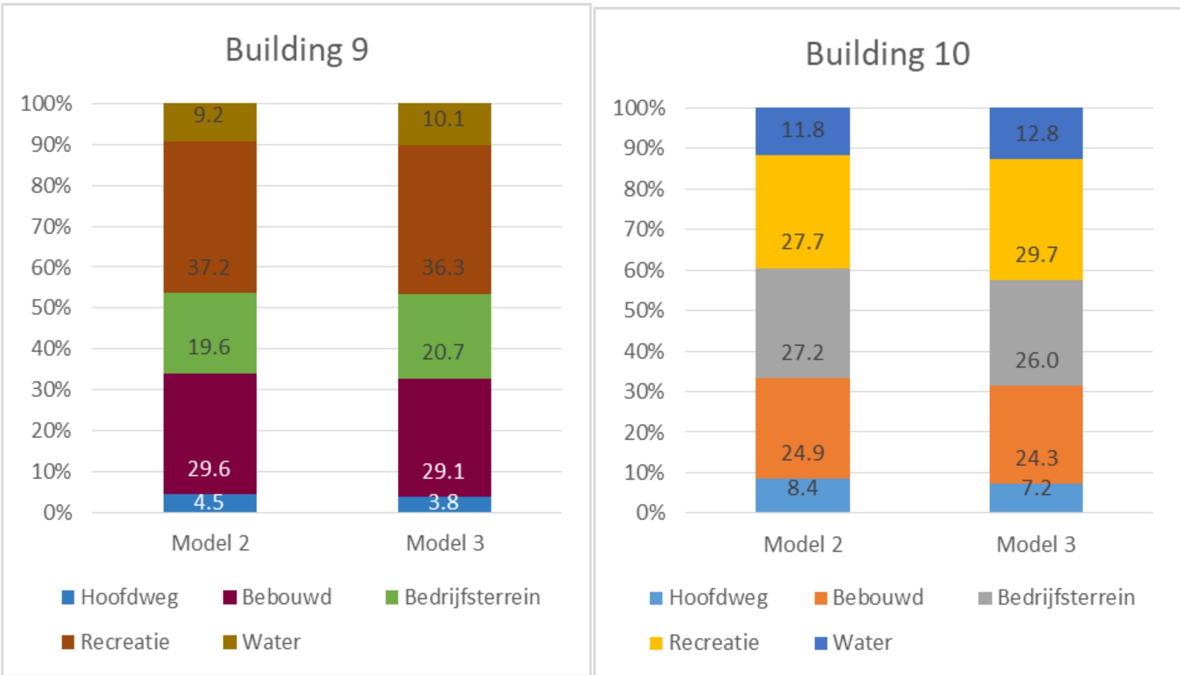

Figure 10. The percentages of view contents of viewshed polygons for 'Model 2' and 'Model3'

So far, the visibility analysis was conducted only for one observer for the each building. This approach may be improved to determine viewshed polygons in different levels of a building. In order to determine the visible areas for two different levels in a building, two observer lines are defined with offsets of -1.3 and -4.3 meters from the building height. Figure 11 presents the visibility polygons for two different level of an observer building. Yellow and red polygons indicate the viewshed areas for last and second last floors, respectively. The visible area determined for the last floor is 6919.31 m², while the last floor has a 17948.75 m² viewshed area.

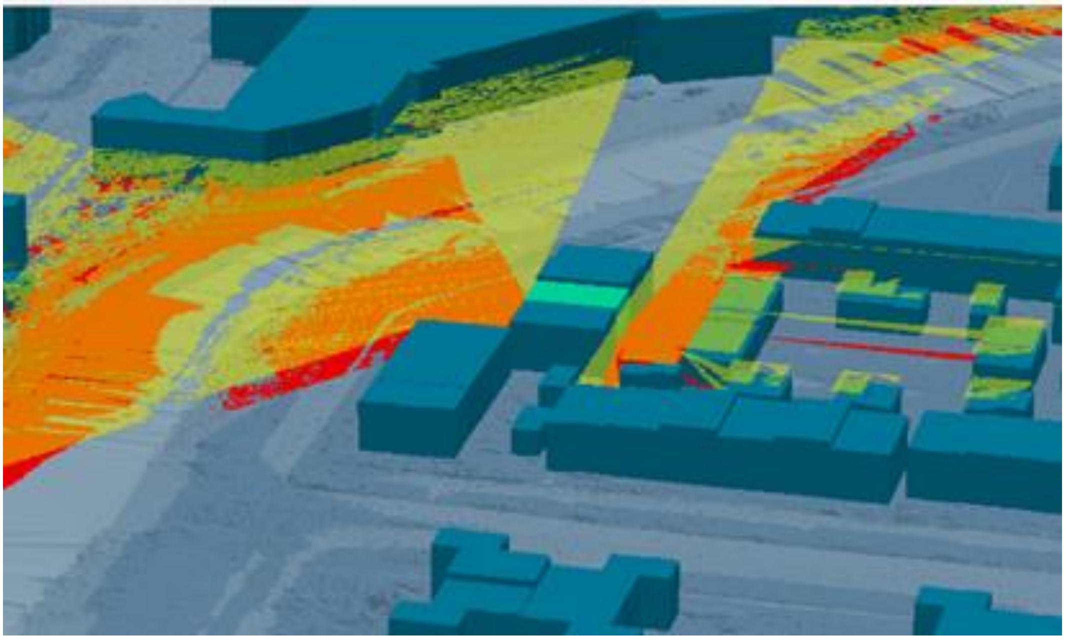

Figure 11. Viewshed polygon for two different levels of an observer building

Property valuation needs detailed information on properties for more accurate viewshed analysis, for example, number of floor in a building, ceiling height of floors and orientation of a condominium unit. It is noted that the open datasets of the Netherlands does not include levels of buildings and condominium units in the levels.

In this section, it is demonstrated that how open datasets of the Netherlands can be used in property valuation activities with different datasets and approaches. In the next section, it is discussed that to what extent it is possible and meaningful to include (derived) environmental and locational characteristics of properties in the LADM Valuation Information Model.

5. DISCUSSION AND CONCLUSION

In this study, it is investigated that which environmental and locational characteristics of properties are used in property valuation activities and how they can be derived from 3D datasets and models via 3D geospatial analysis. It may be concluded that there are indefinite number of environmental and locational characteristics of valuation unit. These characteristics are used in valuation activities depend on purpose and applications. Since there are infinite number environmental and locational characteristics that affect value of a property, the LADM Valuation Information Model does not include them in the first place. However, it is decided that the model can be extended to cover them in different profiles such as 3D valuation unit profiles and country profiles. It may be indicated that some profiles should be developed for the valuation units of LADM Valuation Information Model similar to what has been done for the spatial units in the Annex E of the ISO 19152:2012 LADM in order to tackle different degree of availability of 3D datasets and different demands in terms of regulations to estimate property values. In this context, a 3D profile for the valuation unit class of LADM Valuation Information Model has been proposed as seen in the Figure 12. The proposed profile includes the mostly used environmental and locational characteristics of properties that are derived via literature review. It is noted that most of these characteristics are produced using 3D datasets, models and analyses.

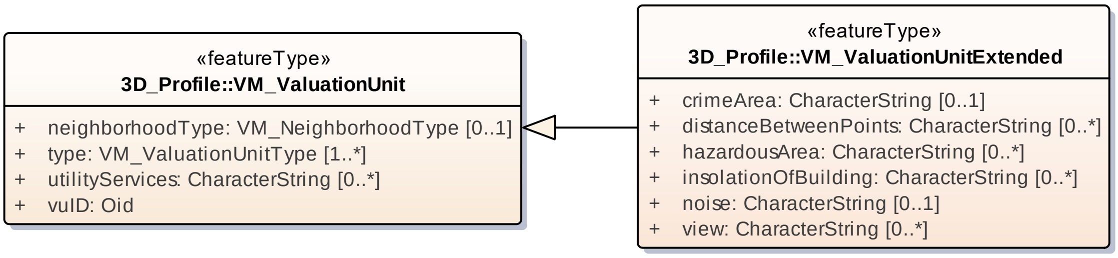

Figure 12. The proposed 3D profile for LADM Valuation Information Model

One of the mostly used 3D geospatial analysis for property valuation is viewshed analysis. In this study, some approaches for viewshed analysis are tested with open data of the Netherlands to show how a viewshed analysis can be used to provide data for view of properties. It may be stated that the point cloud datasets offers a wide range of possibilities for visibility analysis, however, vegetation remains main problem to produce more accurate and reliable visibility data for property valuation (Zhang, 2017). This study also shows that the large-scale maps may be used for visibility analysis in some cases. For example, TOP10NL data can be used for determining viewshed areas of buildings that are not generalized.

Property valuation needs detailed 3D information on properties for more accurate viewshed analysis. If number of floor in a building, ceiling height of floors and orientation of a condominium unit are known or produced in advance, more accurate viewshed polygon may be provided. It is noted that the open datasets of the Netherlands does not include levels of building and condominium units in the levels. As future work, an automatic approach can be developed for determining levels of buildings (Boeters, 2013) and orientation of condominium units in a level of a building. One other future work may be to develop further profiles for LADM Valuation Information Model. For example, a profile may be developed for public law restrictions to show how different spatial restrictions defined in the public domain/law could be better expressed in 3D or derived from existing 2D data sets in order to provide data for property valuation.

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