Web-Based 3D Cadastre's Data Visualization In Indonesia: Challenges And Opportunity

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Keywords: 3D Cadastre, 3D Visualization, Web GIS, BIM, Cesium

SUMMARY

Web-Based GIS (WebGIS) is one of the digital platforms to disseminate spatial information. To implement one map policy, electronic government system, and national geospatial network, the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (BPN) Indonesia has published a geoportal namely Bhumi WebGIS (hereinafter called Bhumi) since 2020. The Bhumi is used to disseminate several geospatial data generated or managed by several directorate generals at BPN. There is a demand for Bhumi to display 3D cadastral data. Government Regulation No. 18/2021 on Rights to Manage Land Rights, Strata Title, and Land Registration support the implementation of 3D cadastral system, especially to support vertical infrastructures development in several cities in Indonesia such as Jakarta, Bandung, and Surabaya. In this paper, Building Information Modelling (BIM) data from 3D modelling of BPN's PUSDATIN building will be visualized on Bhumi along with other supporting data such as DEM Lidar, orthophotos, and 2D land parcels. The platform to visualize these data is Cesium JS with Cesium 3D Tiles and Terrain datasets. This project aims to develop a web-based 3D cadastre prototype capable to represent 3D objects of land parcels (below or above ground) and if possible, to retrieve an attribute database of legal spaces of 3D units similar to the Right Restriction and Responsibility (RRR) concept applied in 2D cadastral. The developed prototype is designed to answer some issues and challenges from previous research such as rendering large 3D data, retrieving legal spaces information, base terrain integration, occlusion management, and interoperability.

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1. INTRODUCTION

Web-Based GIS (WebGIS) is an ideal platform to disseminate spatial information within the institutional scope of work. The Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (BPN/BPN) has published Bhumi WebGIS since 2020 as a realization of Presidential Regulation No. 95 of 2018 on Electronic Government System, No. 27 of 2014 on National Geospatial Information Networking, and No. 39 of 2019 on One Data Policy. This WebGIS is useful for accessing geospatial data generated or managed by working divisions at BPN/BPN, including land parcels data resulting from cadastral activities.

The population density, land use, and economic growth affect the vertically infrastructure development orientation. Therefore, the legal aspect of 3D spaces needs to be studied where this can be resolved by 3D cadastral activities confirmed in Government Regulation No. 18/2021 on Rights to Manage, Land Rights, Strata Title, and Land Registration. 3D cadastre is a cadastral system which registers and provide insight into rights and restrictions not (only) on parcels but on 3D property units (Stoter., 2004).

Aditya et al. (2011) have explained the opportunities of a web-based 3D cadastre to support many urgent applications such as space management and disaster mapping. However, Bhumi WebGIS does not display 3D cadastre data properly and need more improvements to meet visualization requirements for 3D cadastral systems as discussed in previous research (e.g., Shojaei et al., 2013). Therefore, the development of web-based 3D cadastre visualization in Bhumi needs to be implemented in order to be used as a forthcoming technical reference when the 3D land acquisition and registration system is officially implemented in Indonesia.

This project aims to successfully develop a web-based 3D cadastre prototype capable of representing 3D objects on land parcels, below or above ground, and can retrieve attribute info on legal spaces of 3D units similar to the RRR concept applied in 2D cadastral. We used existing 3D BIM data of the BPN/BPN Data and Information Center (PUSDATIN) building along with other supporting data such as DEM Lidar, orthophotos, and existing 2D land parcels. Cesium JS library was used as a framework to visualize these data on web. This JavaScript library has been considered as the most chosen platform for visualizing 3D geospatial data based on previous works. The developed prototype would be enriched with features in order to handle some issues summarized based on previous research and works on the web-based 3D cadastre visualization.

2. RELATED WORKS AND RESEARCH

Stoter (2004) has explained technical recommendations of 3D cadastre such as data modeling, frameworks, database management system (DBMS), and visualization. In visualization, he was concerned with web-based solutions to access 3D spatial objects which organized in DBMS, he also suggested in performance testing of large datasets, 3D cartographic aspects implementation (perspective, stereo, movement, transparency, sticks that indicate the distance between a subsurface construction and the surface level, etc), open-source, and interoperability of data and frameworks provided by OGC (Open Geospatial Consortium).

Shojaei et al. (2013) elaborated the requirements of 3D visualization into three features such as cadastre, visualization, and non-functional features. Cadastre features include handling massive data, functions and queries visualizations, 3D measurement, underground view, cross-section view, and non-spatial data visualization. Visualization features include visual representation and interactivity. Non-functional features include support for technical diversity, system interoperability and integration, usability, and cost.

Cemellini (2018) in her thesis summarized previous requirements (Shojaei et al., 2013) into some issues such as occlusion management, the combination between legal boundaries and reference objects, user experience enhancement, data store, and architecture system. Pouliot et al. (2018) on FIG Best Practice, chapter V concluded that data to be visualized in 3D must be associated not only to physical objects but especially with legal boundaries, which can range from the boundary of the parcels to easements, restrictions, and to the distinction between common and private properties. This indicates that legal space is an important object to be visualized and focused on 3D cadastre.

Indrajit et al. (2020) visualized the 3D representation of RRRs in Bandung and Jakarta using the Spatial Planning (SP) Package and LADM integration as a foundation. Legal spaces in the city need to be represented in 3D to facilitate stakeholders with more relevant information for business purposes. This research indicates the importance of information interoperability and implementation of open data in land management.

Aditya et al. (2011) have developed a prototype of web-based 3D cadastre using X3D format to visualize 3D objects. However, the results of using the X3D format still have many limitations such as the immature 3D representation of terrain surfaces and inconsistent 3D representation detail. The use of X3D format was replaced by CityGML with Cesium JS platform (Aditya et al., 2020). The prototype developed in this project was enriched with data upload features and data management for 3D registration involving various kinds of formats and systems such as KML, CityGML, and PostgreSQL with PostGIS extension. This prototype also adopted Land Administration Domain Model (LADM) specification for data model. This project provides an insight that Cesium JS is an optimal platform for 3D cadastre visualization. However, Cesium JS limits its camera movement for visualizing objects on the ground level or above. Therefore, some additional strategies need to be employed to visualize and interact with 3D cadastre objects situation below the surface or terrain level.

As a development of the previous project, (Building Information Model) BIM data has been used as a data source to be displayed in a web-based 3D cadastre (Aditya et al., 2020). BIM data which is in IFC (Industry Foundation Classes) format was converted to CityGML and visualized in the form of 3D Tiles dataset on TerriaJS which is utilized Cesium JS for 3D visualization. The processing works flow leads to 3D legal spaces determination and validation of BIM formats. Based on related works and research discussed above, occlusion issues and legal spaces have been frequently mentioned. Therefore, some requirements would be proposed in order to handle these issues.

3. ISSUES AND PROPOSED REQUIREMENTS

Based on these related works and research in the previous section, the authors concluded that there were some common issues that needed to be solved for web-based 3D cadastre visualization. Issues explored in this project only focused on the web visualization perspective which is ignoring some other important aspects like system architecture and databases integration. These issues include (1) Rendering large 3D data, (2) Retrieve 3D legal spaces information, (3) Base terrain integration, (4) Occlusion management, and (5) Open and interoperability formats. Some requirements would be proposed to address these issues. These requirements may be a solution for more than one issue as explained in **Table 1**.

Proposed requirements to be implemented were (1) the use of Cesium 3D tiles and terrain datasets usage, (2) layer transparency control, (3) cross-section view, (4) underground view, (5) find and identify legal spaces, (6) simple 3D analyst, (7) first-person perspective, and (8) 3D measurement.

Table 1. Proposed requirements and related issues

No	Proposed Requirements	Issues	Description
1	The use of Cesium 3D tiles datasets	1, 5	This dataset is effective to visualize massive 3D objects data on the web, as well as OGC standard
2	The use of Cesium terrain datasets	1, 3, 5	This dataset is effective to visualize massive terrain data on the web as base terrain of 3D object as well as OGC standard
3	Layer transparency control	2, 4	The transparency function can be used to observe legal spaces and other objects blocked by geometric planes
4	Cross-section view	2, 4	The cross-section function can be used to observe legal spaces and other objects blocked by geometric planes
5	Underground view	2, 3, 4	The underground view function can be used to observe legal spaces and other objects blocked by terrain / under land surface
6	Find and identify legal spaces	2	This function is used to retrieve legal spaces attributes information either by object clicking or by querying entity based on attribute
7	First-person perspective	2, 4	This function is useful for accessing object information directly based on first-person perspective and easily avoiding obstacles

4. METHODS

4.1. Data Acquisition and Format

There were four data used in this prototype obtained from surveying activities. The main data was BIM data from 3D modeling of the BPN/BPN PUSDATIN building. This data would be visualized along with other supporting data such as DEM Lidar, orthophotos, and existing 2D land parcels. 3D BIM data, DEM Lidar, and orthophoto were referenced to the same base station from GNSS (Global Navigation Satellite System) observation so these data had the same coordinate reference system dan height system. The coordinate reference system used was TM3° projection system, while the height system used was orthometric height referring to INA-GEOID 2020. The usage of orthometric height system was important considering that geoid model is an ideal height reference to define the elevation of cadastral objects because of its consistency and physical realization on the earth's surface (Heliani et al., 2013). However, the use of TM3° projection system was not supported by a spatial format that can be rendered in Cesium JS, so all coordinates were converted to UTM Zone 48 S (EPSG: 32748).

BIM data was obtained from the results of 3D LOD 5 modeling generated from the Terrestrial Laser Scanner (TLS) surveying. The Digital Elevation Model (DEM) data was captured from Light Detection and Ranging (Lidar) survey carried out by Unmanned Aerial Vehicle (UAV). The orthophoto was obtained from a geometrically corrected aerial photograph carried by the same UAV. Unlike the other three data, the 2D land parcels data was accessed from existing services owned by BPN/BPN as Web Map Service (WMS) published by GeoServer. Those data would then be converted and visualized through Cesium JS. **Figure 1** is the illustration of data processing flowchart from various kinds of format to the format that can be read and visualized by Cesium JS.

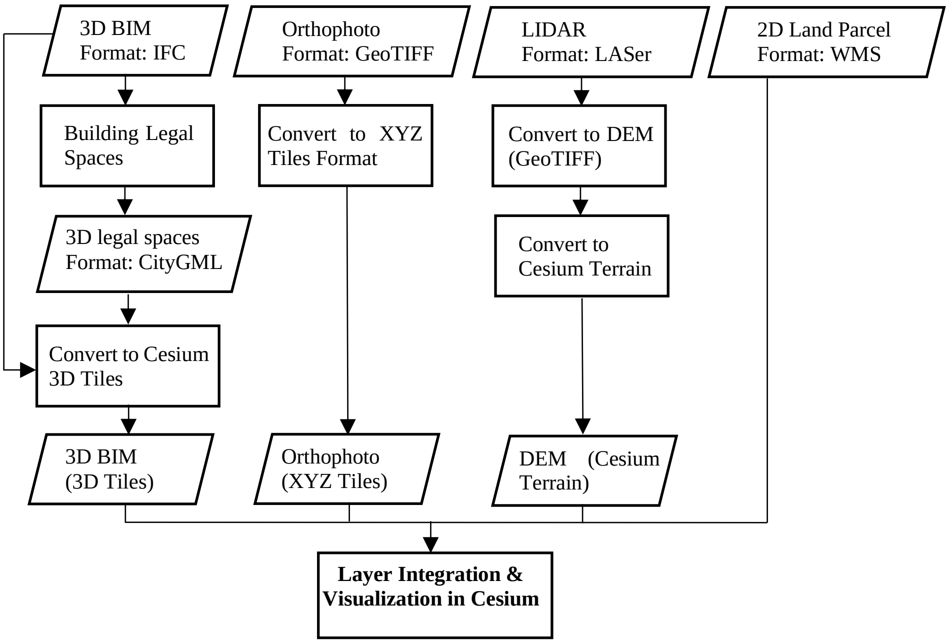

Figure 1. Data processing workflow

4.2. Tools & Technology

This web-based prototype was developed using standard web development languages such as HTML, CSS, and JavaScript with Cesium JS as 3rd party library support for 3D web map. Cesium JS has been considered as an open-source framework for accurate 3D visualization on the web, high-precision (WGS84) digital globe, and the fastest available pipelines for creating 3D Tiles from heterogeneous data (Cesium JS, 2022). The developed prototype would be integrated with Bhumi, published geospatial dashboard for BPN/BPN data.

The data processing in this paper involves the utilization of both open-source and enterprise software. However, the author in this paper would minimize the use of enterprise software and strive to find open-source solutions. The eveBIM software was used to determine 3D legal spaces and their attributes. The Feature Manipulation Engine (FME) software was used to convert 3D BIM and legal spaces data from IFC and CityGML to Cesium 3D Tiles datasets. For orthophoto and DEM Lidar data processing, Quantum GIS (QGIS) software was used for data conversion with QTiles plugins and LASTools support.

5. 3D BIM DATA PROCESSING

The use of BIM has been emphasized by the regulation of the Ministry of Public Works and Housing number 22/2018 regarding the Construction of State Buildings. In addition, the use of 3D and BIM formats for cadastre 3D needs had been also emphasized in the BPN/BPN regulation number 16/2021 regarding land registration. The original BIM data that obtained from third-party vendors was in Revit format. In this paper, the Revit format would be converted first to the IFC (Industry Foundation Classes) format. The benefit of using this format is interoperability, this format is an open file format specification that does not depend on one type of software or platform. IFC has become a global standard for data exchange in the building industry. As explained in the previous section, in this paper the author avoid using enterprise software, while Revit format requires Autodesk Revit for processing (Enterprise software). IFC format can be opened in open-source software such as eveBIM to be visualized as in **Figure 2**.

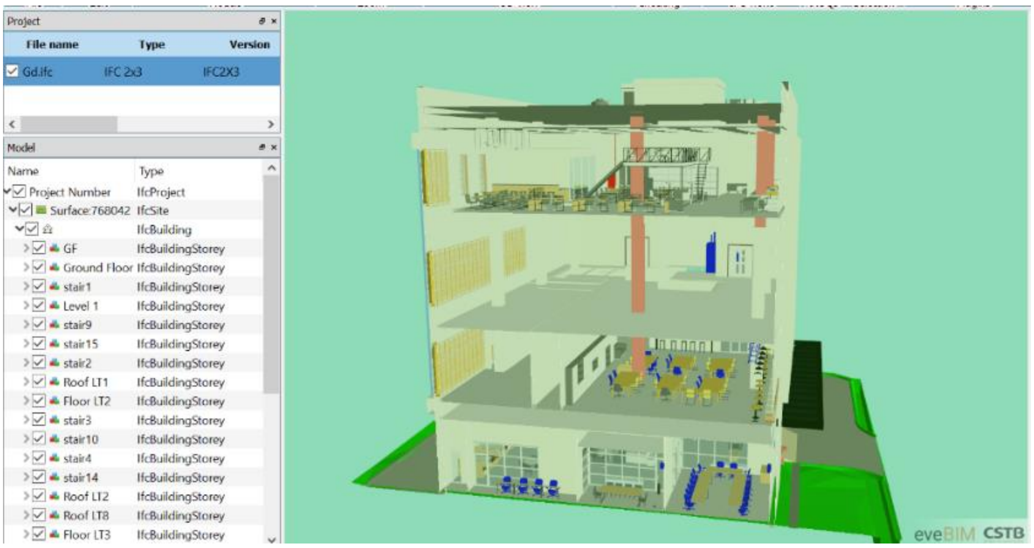

Figure 2. PUSDATIN MoASP/BPN BIM data displayed in eveBIM

5.1. Legal Spaces Determination

Legal spaces are natural spaces that have a certain legal relevance (S Müller-Mall, 2013). This terminology has been widely cited in many cadastre journals to describe the spatial object along with its boundary related to the interests of RRR (Rights-Restrictions-Responsibilities). Based on LADM, legal spaces of buildings and utility networks are part of the spatial unit's package. Legal space is a space for the land administration (bounding envelope of the object) (LADM, 2012). Many research examines how to build legal spaces from BIM. While BIM models physical infrastructure, LADM works from the perspective of legal spaces (Oldfield et al., 2016).

Donkers et al., (2016) converted IFC building models into geometrically valid and semantically rich LOD3 CityGML models. Oldfield et al., (2016 – 2017) used IFC elements of BIM model (IFCSpace and IFCZone) to define cadastral legal spaces. This method was also implemented by Aditya et al., (2021) to gain legal spaces by selecting walls, floors, and ceilings for each unit as IFCSpace, then converted to CityGML using eveBIM. Atazadeh et al., (2019) queried BIM physical elements to identify legal spaces along with their topological relations.

In this paper, legal spaces would be a spatial entity that can be identified together with its semantic information. Besides the limitations of existing data, the author was not focused on legal aspects, but rather on the technical aspects to visualize 3D cadastre on the web, so legal spaces could be indicated as a meeting room, workingspace, lobby, or the other common property of the PUSDATIN 3D building model. IFC elements were filtered from unnecessary parts such as building interiors. The elements required to create legal spaces, in this case, were IfcBuildingElement, IfcWall, IfcWallStandarCase, IfcSlab, and IfcCurtainWall. **Figure 3** illustrated Floor LT4 before and after elements selection.

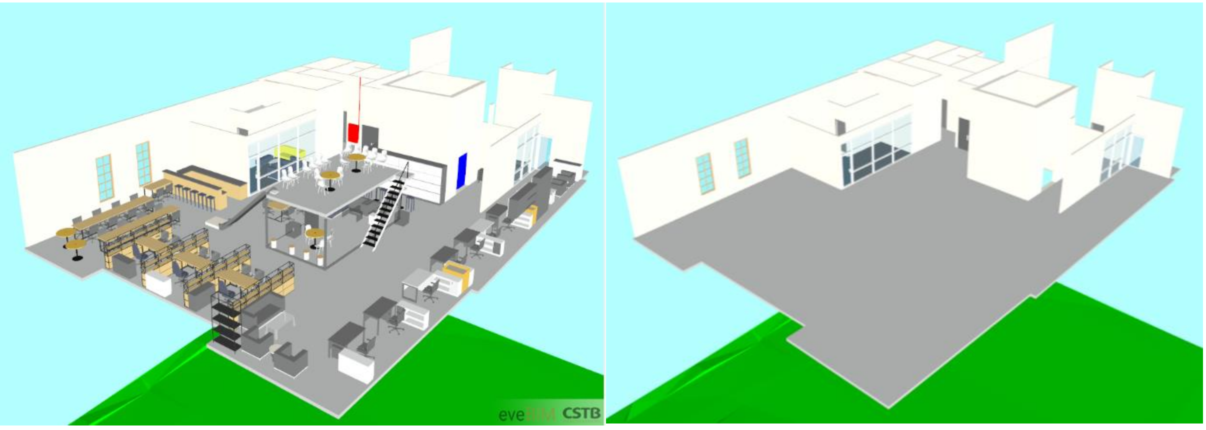

Figure 3. IFC building before elements selection (left) and after elements selection (right)

Element selection was done to facilitate the process of identifying legal spaces. After that, the edges and vertices coordinated in each room (legal spaces) would be identified in the plan view by selecting IFCBuildingStorey for each level. Those coordinates then would be plotted in CityGML format. **Figure 4** is the illustration of the plan view while legal spaces determination process in the plan view and the 3D of legal spaces in CityGML format.

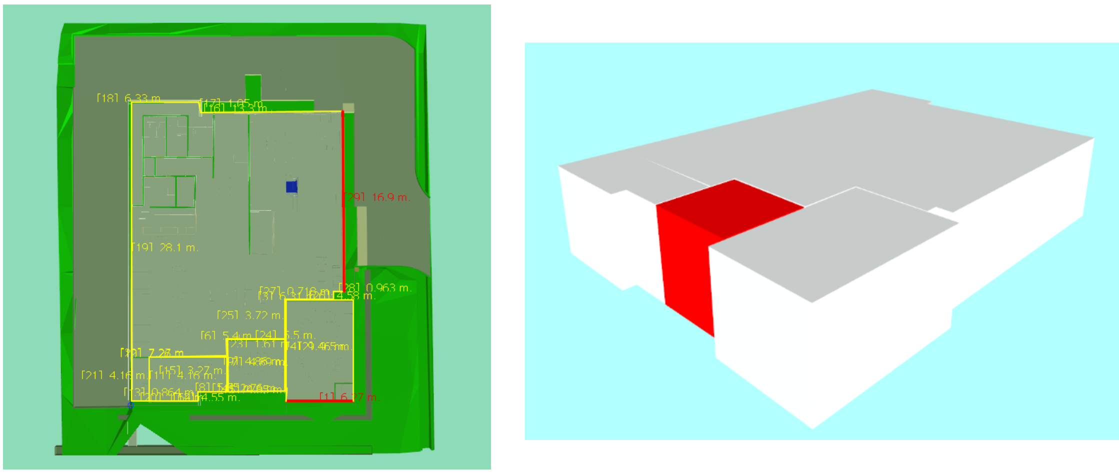

Figure 4. Legal spaces determination process in plan view (left) and the result in CityGML format (right)

Some legal spaces boundaries were digitized in the outer part of the wall. In LADM (2012), legal spaces were usually larger than the physical extent of the object itself (for example including a safety zone), this concept can also simplify the process of identifying legal spaces when visualized alongside with the 3D physical building model.

Attributes information was added to legal spaces CityGML either by utilizing properties interface in eveBIM, or embeding directly to CityGML code. In this paper, the author focus was on creating 3D building that was visualized on the web that can provide the attributes info to users, therefore the author only put three fields as semantic information examples. Of course, separate discussion and study are needed regarding the table design that needs to apply the concept of LADM or legal/technical aspect of internal standards on land registration. These fields were "right_type", "owner", and "object_id" as a primary key. For this prototype development, the author used the type of rights based on Government Regulation No. 20/2011 on strata tiles such as ownership rights of strata tiles (SHMSRS), ownership rights of the building (SKBG), land management rights (HPL), and common ownership rights. The owner field described the name of individual or community own the object of legal spaces. The object_id was very important because this field serves as the primary key or unique identity of legal spaces.

Field Name	Data Type
object_id	Integer (PK)
owner	String
right_type	String

```
<gen:GenericCityObject>
    <gen:intAttribute name="object_id">
        <gen:value>0001</gen:value>
    </gen:intAttribute>
    <gen:doubleAttribute name="owner">
        <gen:value>Akhmad Faizal</gen:value>
    </gen:doubleAttribute>
    <gen:doubleAttribute name="right_type">
        <gen:value>SHMSRS</gen:value>
    </gen:doubleAttribute>
    <gen:lod4Geometry>
        <gml:Solid srsDimension="3">
            <gml:exterior>
```

Figure 5. Table design and its assignment to CityGML

5.2. Legal Spaces Determination

Cesium 3D Tiles is designed for streaming and rendering massive 3D geospatial content such as photogrammetry, 3D buildings, BIM/CAD, instanced features, and point clouds (Cesium Inc and OGC, 2018). This format is open-source and has been set as an OGC standard to display heterogeneous 3D geospatial data. Tree spatial data structure is implemented on Cesium 3D Tiles where the top of the hierarchical tree is bounding volume as the extent of each tile or 3D object, this structure is optimal to rendering or encoding 3D object reminding that there would be a lot of 3D cadastre object displayed in one web-based map in the future development. This concept is similar to the implementation of map tiling in WMTS or XYZ tiles that are already used for imagery base map and 2D cadastre visualization (E.g., land parcels). The software used to convert both BIM IFC and CityGML data to Cesium 3D Tiles is FME. All IFC features merged into one general object then converted to Cesium 3D Tiles. **Figure 6** shows the PUSDATIN BPN/BPN 3D building and legal spaces displayed on Cesium.

Figure 6. MoASP/BPN PUSDATIN building (left) and legal spaces with interior (right) in Cesium 3D Tiles Datasets

6. DEM LIDAR AND ORTHOPHOTO DATA PROCESSING

6.1. Generate XYZ Tiles

XYZ tiles is web map tile format to display multiple images as a base map in web. This structural format is used by OpenStreetMap and become standard to visualize OSM base map. Although this format is not OGC standard like WMTS or WMS, the ease in generating and serve XYZ format as a service become the consideration why the authos chose this format.

In this paper, the author used this XYZ tiles format to display orthophoto raster data in Cesium. Format conversion from GeoTIFF to XYZ tiles was generated by using QTiles plugins in QGIS software. The single file of GeoTIFF would be split into little raster image tiles with various resolutions. Instead of visualizing all images at once, XYZ tiles only used original spatial resolution (0.1 meters for each cell size) in the highest zoom level and encode each tile as a separate request to web. There would be size and resolution reduction for each image in lower zoom level. This hierarchical concept of raster image resolution makes this structural format effectively rendered.

Figure 7. Orthophoto as XYZ Tiles

6.2. Lidar DEM to Cesium Terrain Conversion

Cesium Terrain is Quantized Mesh Format to fast render 3D objects on Cesium. The level of detail is controlled by zoom level and each terrain is splitting into a single tile with coverage, so the algorithm indicates that only terrain on-screen with specific LOD will be rendered. This algorithm will be very effective when applied to wide terrain coverage, considering the possibility of creating more precise terrain base from DEM data for national coverage.

Visualization in this project involved terrain data from Lidar DEM to represent the real topographic surface of 3D cadastre objects, reminding that 3D legal spaces could be above or below ground (Government Regulation No. 18/2021). Indrajit et al. (2020) also recommended local governments to provide an accurate Digital Terrain Model for the entire urban area using mapping technologies like Lidar. Existing Lidar DEM data was still a point clouds with LAS format. However, point clouds data couldn't be converted to Cesium Terrain directly, so we converted Lidar data from LAS format to GeoTIFF as Digital Elevation Model (DEM). The conversion format was processed using LASTool in QGIS.

In this paper, the author used Cesium-ion to generate Cesium Terrain. Cesium World Terrain was used as base terrain to fulfill the missing terrain outside our DEM coverage. Figure 8 illustrates the result of Cesium Terrain rendering based on our Lidar DEM data. Terrain outside our DEM area (outside white outline boundary) is Cesium World Terrain. Cesium World

Terrain fuses several data sources into a single quantized-mesh terrain tileset. In Indonesia coverage, specifically around PUSDATIN 3D building as our study area, the default terrain used is SRTM (Shuttle Radar Topography Mission) (Cesium JS, 2022).

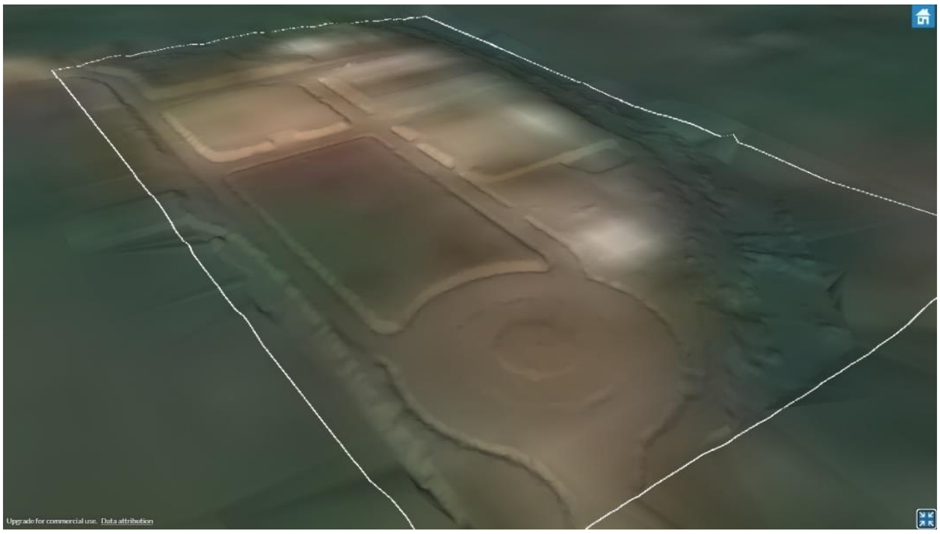

Figure 8. DEM Lidar as Cesium Terrain format in Cesium

7. DATA VISUALIZATION IN CESIUM

The prototype was developed using Node.js as a runtime machine and Cesium JS as 3D JavaScript framework. The source code would be deployed to the existing Bhumi platform. However, the existing Bhumi platform was installed by using TerriaJS template which is based on authors experience's, this template didn't easily support scalability for Cesium features. Therefore, this prototype would be deployed separately from existing 3D features.

Data integrated with this prototype were 3D building models, legal spaces, orthophotos, Lidar terrain, and land parcels in WMS. The use of orthophotos imagery gave us more accurate representation of the base map as illustrated in **Figure 9**. Orthophotos in XYZ Tiles as a base map would be automatically draped to Lidar Terrain. As discussed in the previous section, this combination also represents more realistic environment for 3D building base terrain as we can see in **Figure 10** by comparing the visualization without lidar terrain in the same position and camera view.

Figure 9. Orthophotos (left), default Cesium imagery (right)

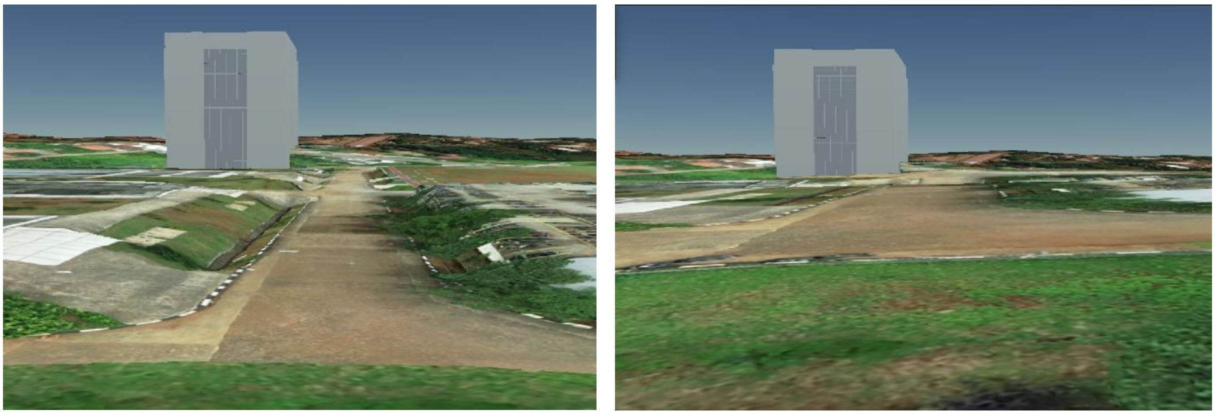

Figure 10. Cesium terrain from Lidar DEM (left) and default terrain

The 2D land parcels as WMS also would be automatically draped to Lidar terrain when this service was accessed as illustrated in **Figure 11**. The 3D building of BIM data would be displayed without feature identifying capability, so this data was only for visualization which proposed to be compared with legal spaces. However, legal spaces data has feature identifying capability. The ownership attributes in this object could be retrieved by the users reminded that this would be the main focus on 3D cadastre.

Figure 11. 2D land parcels in WMS displayed on Cesium JS

8. SOURCE CODE DEVELOPMENT

This section will explain the result of source code development based on the proposed requirements listed in Table 1. The realization of proposed requirements was categorized based on function development and the use of formats or standards. Rendering massive data issues could be solved by using format such as Cesium 3D tiles and Cesium terrain. As explained in the previous section, these formats were designed to handle massive data. In addition, these formats could also be considered as open-source and interoperability. The other issues were handled by functions development as detailed in this sub-section.

8.1. Layer Transparency Control

Cemellini, (2018) mentioned layer transparency control functionalities in 3D cadastre visualization to handle occlusion issues and topographical issues. In this prototype development, this function allowed us to manipulate layer opacity levels and helps us to observe important objects like legal spaces that were blocked by other objects or layer shells. This function also was implemented on terrain, so that we could observe underground objects through the base terrain. **Figure 12** shows us how layer transparency approaches is useful to access legal spaces objects blocked by building walls or terrain.

Figure 12. Access legal spaces information blocked by walls (left) and terrain (right) with transparency capability

8.2. Cross-Section View

The cross-section view is useful to observe 3D objects inside the building by clipping the building parts or elements. The clipping plane can be oriented in a different way (Shojaei et al., 2013), however, in this project it could only be arranged horizontally or vertically. Horizontal clipping plane could help us to identify objects based on building level. Meanwhile, the use of vertical clipping plane is useful to observe 3D objects in all levels inside the building. **Figure 13** illustrated the use of the cross-section view in Cesium JS.

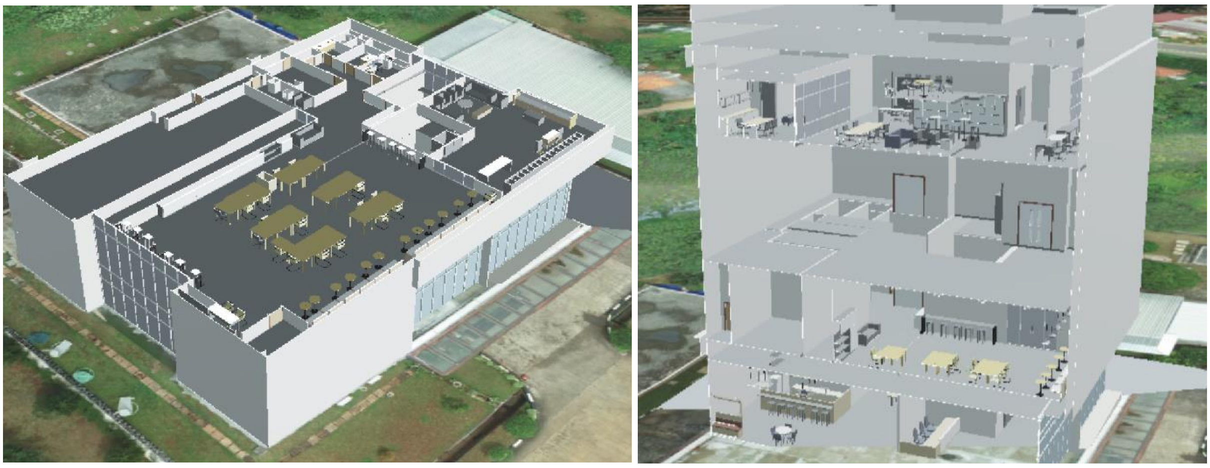

Figure 13. Cross-section view horizontally (left) and vertically (right)

8.3. Underground View

Atunggal et al., (2021) indicated that 3D cadastre objects (sub-surface station) can be 17m below the land surface. In the visualization case, this condition required underground view implementation. The underground view function developed in this prototype allowed us to identify legal spaces under base terrain. However, the underground legal space determined in this project was not derived from BIM of PUSDATIN building, but fake legal spaces digitized to represent underground utilization that is commonly found in buildings for testing proposed. Users' 3D view orientation control could be navigated to underground view and also view objects that were plotted below the topographic surface. The vertical accuracy between terrain and 3D objects data is important to avoid misleading information related to the elevation of 3D object and its relativity to base terrain. **Figure 14** illustrated the underground view function. This function is an alternative solution for accessing underground legal spaces objects instead of terrain transparency.

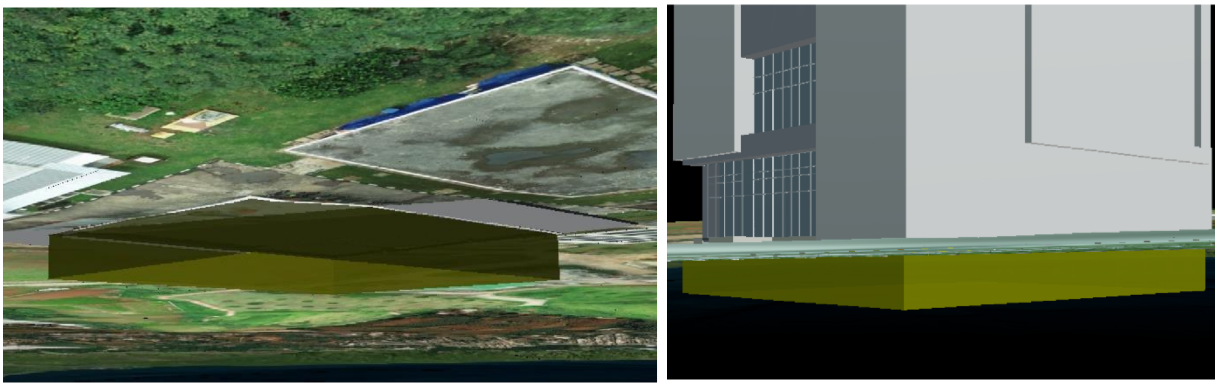

Figure 14. Legal space object identified in underground view

8.4. Find and Identify Legal Spaces

Identifying spatial functionality is a mandatory function that needs to bed existed in any kind of GIS platform. This function allows us to click spatial objects and retrieve attribute information related to clicked feature. As already implemented in 2D cadastre visualization, this function is useful to identify 2D land parcels as geometry with RRR interest. In this project, this function was also implemented to retrieve information from 3D legal space. However, identifying interest objects method by manually navigating and clicking is sometimes hard to be practiced. Therefore, finding legal spaces by attribute queries was also implemented. The field used for legal spaces queries was "object_id" remind that this field was primary key. After providing input value "object_id", the find button needed to be clicked so the 3D scene would automatically fly to legal spaces with selected "object_id". **Figure 15** illustrated the attribute queries process to find legal spaces based on "object_id".

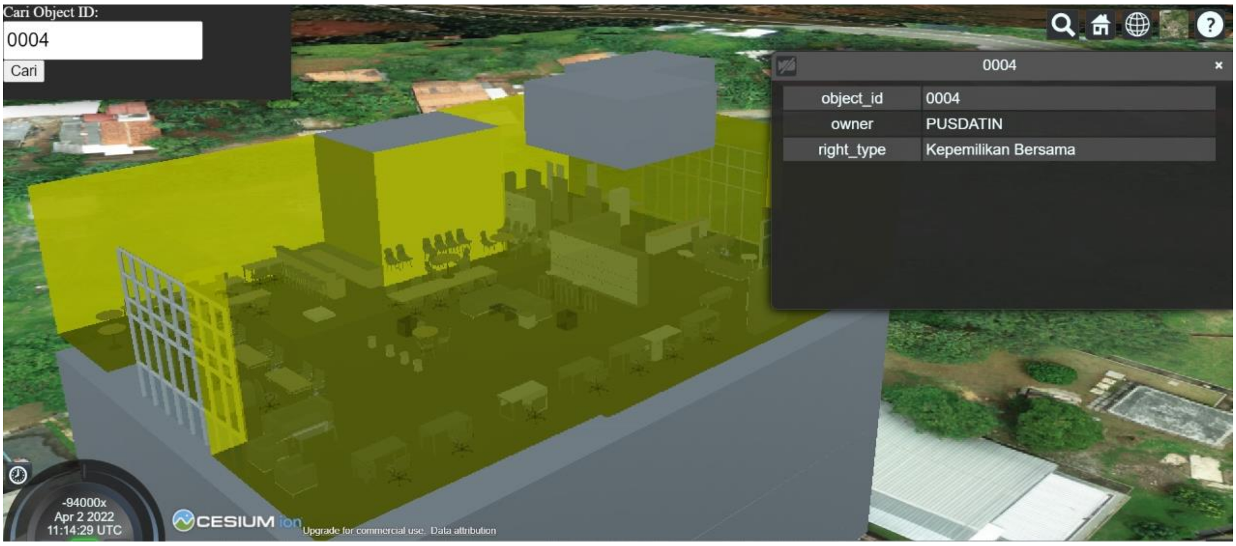

Figure 15. Legal space found by "object_id" queries

8.5. First-Person Perspective

Laksono et al., (2019) implemented the first-person view for 3D city interactivity and showed that first-person perspective was useful to explore land right type and values through a walkable 3D city neighbourhood. This function was also implemented in this project in order to identify legal spaces obstructed by objects geometry. The first-person perspective allowed us to walk freely and look around to observe the topography and building interior. In addition, the use of this function also allowed users to conduct virtual tours which is a good approach for stakeholders. The "W" key is used to move forward, the "S" key to move backward, the "E" key to move left, and the "D" key to move right. **Figure 16** illustrated the legal spaces identifying process inside the building in first-person mode.

Figure 16. Identifying legal space inside the building in First-Person

7. DISCUSSION AND CONCLUSION

The web-based 3D cadastre prototype has successfully developed and handled several issues related to 3D data visualization such as rendering massive data, terrain integration, and occlusion handling. This prototype also integrated with Bhumi although it is still in separate features remind that Cesium JS in Terria used by Bhumi is difficult to be expanded or updated. The next development version of Bhumi would be considering scalability issues so that the features developed in this prototype can be directly integrated.

The use of Cesium 3D Tiles dataset is effective in rendering 3D data for both physical objects and legal spaces. This dataset can be considered for future work when 3D city models with large number of objects for cadastre are rendered. In addition, this format is also interoperable and listed as an OGC standard. This format can be directly generated from many BIM formats like IFC, CityGML, and Revit. However, software used to generate 3D Tiles like FME is not fully open-source, while the Cesium ION has limited storage (less than 5GB). Although BIM data processing commonly still requires enterprise software such as AutoCAD Revit, what needs to be focused on in 3D Cadastre is how to generate legal spaces from existing BIM. 3D data in Cesium 3D tiles format also need to be published as services so it can be consumed by many platforms. The legal spaces visualized as 3D tiles also effective remind that semantic capability to store attribute information about legal and ownership in Cesium 3D tiles. In the future, there needs to be technical guidelines regarding legal spaces, both in terms of geometry and legality

In this paper, the use of Cesium terrain format has been tested to render terrain from DEM Lidar and produce more realistic 3D environment that represents real topographical conditions. Just like Cesium 3D tile, this format also can be considered to use in future work to publish more accurate DEM as 3D terrain. The DEM data can also be sourced from DEMNAS (DEM Nasional from BIG) as default if locally Lidar data is still not available. The ability to explore underground objects is very appropriate considering the need for cadastral below and above ground. However, sometimes the navigation in the underground is difficult to control, in future development, this capability can also be applied to push terrain instead of just underground view. Another issue is about the platform to produce Cesium terrain which require open-source solutions. Cesium terrain still needs Cesium ION with limited storage, another alternative is to use Maptiler which is not fully open-source. Similar to Cesium 3D tiles, this dataset also needs to be published as a service.

The development of this prototype can handle occlusion related problem that commonly occurs in 3D data visualization with several functions such as transparency control, cross-section, and first-person functions. These functions still need to be innovated. However, the future development of web-based 3D cadastre as discussed above still has various aspects that need to be noticed such as:

1. The integration of the 3D tiles format with the database. The land cadastre is now stored in the BPN/BPN internal system called KKP. Therefore, the data presented for 3D cadastre must also be integrated with this database. The possibility of querying, updating, and manipulating 3D cadastre requires a Database Management System (DBMS). The 2D data like land parcels, land value zone, land use which are now presented in WMS format are

sourced from spatial data stored in DBMS, therefore 3D cadastre data must be treated as such, which is then published in fast rendering 3D format (Cesium 3D tiles for current development)

2. The implementation of microservices architecture. Just like 2D data that has been presented in the form of services (WMS). Each of the Cesium 3D tiles, terrain, and XYZ tiles needs to be set up as services. This will affect the scalability of the web-based 3d cadastre system so that each system can be expanded and updated easily both in data storage or feature improvement.

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