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3D Modelling, Validation and Visualization of 3D Parcels in First Registration for 3D Cadastre - Indonesia Case

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Key words: 3D modelling, field validation, 3D visualization, first registration

SUMMARY

Developments of legal, institutional and technical aspects in realizing property registration of 3D parcels situated above and below 2D parcels are still evolving in many countries. 3D cadastres have to deal with various institutional/legal gaps and challenging information integration regarding the Rights-Restrictions-Responsibilities (3R) of 2D parcels. This paper aims to present a proof of concept implementing 3D cadastre of a new regulation of land registration in Indonesia (Government Regulation Number 18/2021 on Rights to Manage, Land Rights, Strata Title and Land Registration). This study presents the modelling and validation of 3D cadastral objects for realizing the first registration using the new regulation on 3D cadastre. The study encompasses 2D & 3D data integration, 3D modelling, field validation and visualization of 3D units. The 2D parcels were extracted from the land registration map, collected from the Central Jakarta and the South Jakarta land offices. The 3D constructions to be registered were obtained from PT. MRT in the form of as-built drawings of floor plans and selected cross-sections. The 3D models were created by reconstructing 2D floor plans and cross-sections using Autodesk Revit to create an IFC file of 3D units from geometries of floors, walls and ceilings. Surveyors validated 3D representations of 3D units of two MRT terminals. Field validation includes determining the legal spaces against the 3D constructions and validating floor areas and volumes of 3D units. After field validation is done and agreed upon by stakeholders, 3D models were converted into CityGML to create representations of legal spaces of 3D units. The tools used to convert IFC into CityGML 2.0 are Sketchup City Editor and eveBIM. Data conversion results must be cleaned and edited to include the semantic of 3D units and registration attributes. The results of the integration of 2D and 3D parcels are presented in Terria Map, which shows the constructions, legal spaces of 3D units and 2D parcels with rights.

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1. INTRODUCTION

In Indonesia, land administration is considered one of sectors requiring substantial improvement, especially regarding its time, cost and procedures. The country score for property registration in Ease of Doing Business (EODB) measures has been below 70 for years (The World Bank 2021). The government of Indonesia recently unleashed Jobs Creation Law, commonly referred to as the "Omnibus Law". Indonesian parliament passed the Omnibus bill on 5 October 2020 and was signed by the President on 2 November 2020. This law covers many clusters, including business licensing, investment ecosystem, workforce, forestry, environment, taxation and land administration. Regarding land administration, the government acclaimed the omnibus law to provide new legal frameworks that support EODB reforms on land banks, rights to manage, strata titles and land registration for 3D parcels below and above ground.

Article 146 from the omnibus law specifies that 3D parcels located below or above ground can be used for certain activities by parties. A 3D parcel is entitled to one of the following ownership types: rights to manage (known as *Hak Pengelolaan*/HPL), rights to build (*Hak Guna Bangunan*/HGB) and rights to use (*Hak Pakai*/HP). The government launched a new regulation number 18/2021 (Government Regulation Number 18/2021 on Rights to Manage, Land Rights, Strata Title and Land Registration) to empower legal and intuitional aspects of land registration which includes registration to 3D parcels either above or below ground. The articles regulating 3D cadastral objects, types of rights (including their required permits and approval), parties and administrative arrangements are specified from Article 74 to Article 83 in this government regulation.

As 3D cadastres have to deal with various institutional/legal gaps and challenging information integration regarding the Rights-Restrictions-Responsibilities (3R) of 2D parcels, appropriate guidelines and standards for implementing this new regulation is necessary. At the moment, land administration in Indonesia is focusing only on 2D representations. This paper presents the results of a pilot study involving the government Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (MoASP/BPN), the university (Universitas Gadjah Mada/UGM) and the user (PT Mass Rapid Transit Jakarta/MRT). The study took place from July to August 2020 in two newly built Mass Rapid Transportation (MRT) terminals in Jakarta City. This paper is a part of studies related to implementing 3D cadastre in Indonesia, collaborating with the National Land Registry Agency of Indonesia (BPN). The focus of this paper is to set the stage for 3D cadastre initial registration to understand an ideal pipeline for the MoASP/BPN officers in implementing the newly issued regulation on-field surveying for

3D cadastre. The study encompasses 2D & 3D data compilation, 3D modelling, field validation and visualization of 3D units.

Section 2 will give a short literature review regarding data modelling and visualization. Section 3 will first describe the procedures and methods in creating and visualizing 3D models for the first registration mission. Section 4 will present the results of the pilot study. Section 5 will highlight essential elements in creating the national guideline for 3D cadastre implementation and some issues to be resolved in the future.

2. LITERATURE REVIEW

Developments of legal, institutional and technical aspects in realizing property registration of 3D parcels situated above and below 2D parcels are still evolving in many countries. Despite many examples of partial implementation of first registration, no country has a fully functional 3D cadastre (Dimopoulou et al. 2018). That is also true for the case of Indonesia land administration. The strata title registration mandated by the Law number 20/2011, can be regarded as an early implementation of 3D registration in Indonesia land administration. The law (created first in 1985 as the Law number 16/1985 and then revised into number 20/2011) allows the government to give parties their ownership rights of individual units in addition to common rights within the building. For this purpose, a field survey to validate the boundary units (spatial data) and underlying documents (legal/administrative and party data) should be done by the land office where the application is submitted. In order to improve the certainty regarding the validity and representation of spatial and legal data of individual 3D cadastral objects, a relevant 3D survey and mapping procedure for the country has been tested for some 3D objects (Aditya et al. 2020). In the proposed procedure, land surveyors can create 3D models for the 3D cadastre registration from field survey or digital reconstruction generated from the file submitted by the users.

Over the past two decades, various 3D data models for 3D cadastre have been implemented without or with semantic enrichment to the geometry. eXtensible Markup Language (XML)-based data models such as Keyhole Markup Language (KML) and COLLADA with limited or no semantic information have been used as data exchange formats to display simple 3D representations of parcel units for web 3D cadastre (Aditya et al. 2011). The approaches for semantic enrichment for 3D cadastre can be realized using two data formats, i.e., Building Information Model(BIM) /Industry Foundation Classes (IFC) (e.g., in Atazadeh et al. 2019; Olfat et al. 2021) and 3D CityModel using the OGC's City Geography markup Language(CityGML)(e.g. in (Biljecki et al. 2021; Eriksson et al. 2021). Both options, i.e., BIM/IFC oriented and 3D CityModel approach, are required to be able to represent two types of boundary representations: physical and legal boundaries or spaces of Rights-Restrictions-Responsibilities (3Rs) in 3D cadastres.

In order to represent both physical and legal boundaries, researchers have investigated the integration of legal and physical models. Atazadeh et al. (2018) explored the matching between IFC data format as the physical model and Land Administration Domain Model (LADM) as the legal reference model. Li et al. (2016) realized the integration between

CityGML and LADM by adding an Application Domain Extension (ADE) for CityGML to precisely reveal legal objects' ownership structure regarding their physical objects in a condominium unit.

Both options of IFC-cadastral extension to LADM and CityGML-LADM ADE (currently) do not have built-in support for 3D cadastre and needs to rely on ADE for storing 3D cadastre data. However, for this pilot study, CityGML ADE is better and more matured for supporting 3D legal spaces and building objects (e.g., Rönsdorf et al. 2014; Donkers et al. 2016) compared to IFC's ADE support for property and built environment such as road network (Lee and Kim 2011; Atazadeh et al. 2021).

Although we realized that the options for a comprehensive legal and physical boundary representation would be: CityGML-LADM ADE or Cadastral Extension of IFC, we did not explore those two options equally from the data modelling into data visualization as two separate cases (for further comparison). Instead, we considered IFC-based data modelling as the standard approach for data modelling and processing for 3D constructions, while CityGML as the data format for 3D cadastre visualization. This pilot study creates 3D models from the building as-built (ABD) drawing, submitted by the user to MoASP/BPN. This CAD file has been considered as the standard format provided by the existing 3D building and infrastructure users who apply for existing regulated construction permits in big cities in Indonesia. Thus, in this pilot study, the data modelling and validation were managed using IFC and data visualization was done using CityGML. This approach was also undertaken for some practical reasons:

- This study will be used by the MoASP/BPN to develop a national technical guideline for land surveyors to conduct survey and validation activities for unregistered 3D parcels below or above ground. Hence the focus is on the 3d modelling and validation using Computer Aided Drawing (CAD) applications that support IFC/BIM as it was applied for surveying and mapping 2D parcels in using CAD and geopackage as data input format (see, e.g., (Aditya et al. 2021);
- The MRT case study is an ideal situation for CAD/BIM formats suggested by earlier regulations for 3D Building development in Indonesia. Government regulations have favoured BIM standards (e.g., The regulation of Ministry of Public Works number 22/2018 and the Government regulation No. 21/2021 on level-5 BIM and level-8 BIM implementations for national projects).
- a new data model reengineering study in MoASP/BPN is still in progress, including recommendations for physical and legal boundary representations for 2D and 3D cadastre integration.

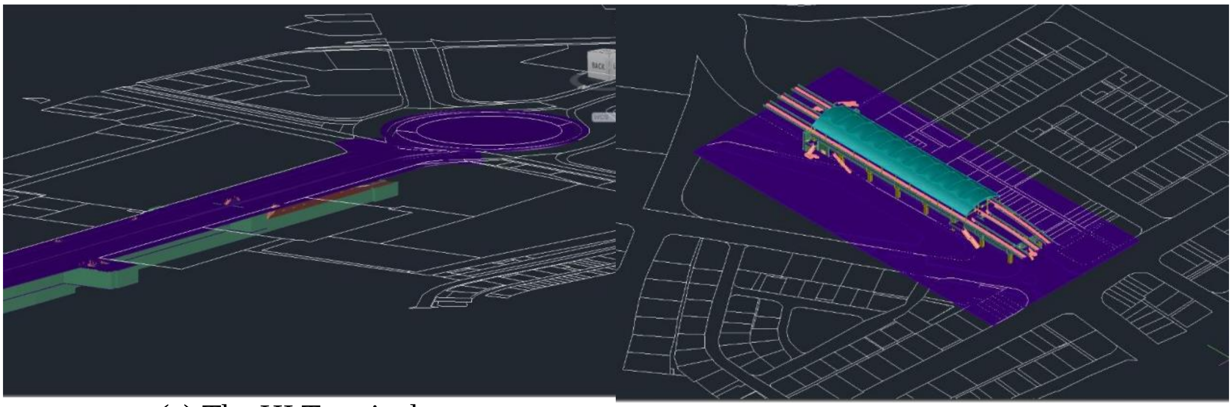
3. IMPLEMENTATION OF THE PILOT STUDY

3.1. Study Areas

The study took place in two newly built Mass Rapid Transportation (MRT) terminals at Hotel Indonesia Roundabout (HI) and Blok M Square (Blok M) in Jakarta, managed by PT. MRT, a municipally-owned corporation. These two MRT terminals are among The Phase-1 MRT

Jakarta development (MRT 2020) and was fully operational when the study was undertaken. The field validation was done in close cooperation with the PT. MRT as the operator and the MoASP/BPN. Figure 1 shows the 2D parcels surrounding both terminals. The 2D parcels where the terminals are built are land assets managed by the Special Capital Region of Jakarta Province.

In this pilot study, party identity and the underlying documents that applicants typically submit in the first place in case of 2D first registration are assumed to be clear and clean. The registration system from the MoASP/BPN will forward the user application to the surveying and mapping section to validate spatial objects. Here, the land surveyors from MoASP/BPN typically require a working map showing the situation of existing 2D parcels to ensure the location is correct and valid and the status of 3D parcels. The 2D parcels were extracted from the land registration map, collected from the Central Jakarta and the South Jakarta land offices. Meanwhile, the 3D constructions to be registered were obtained from PT. MRT in the form of ABD of floor plans and selected cross-sections.



(a) The HI Terminal (b) The Blok M terminal

Figure 1. the study areas for the pilot study of two MRT terminals in Jakarta (Atunggal et al. 2020)

3.2. Data Modelling

The 3D models of spaces to be registered were created based on the digital version of the as-built drawing (ABD) plan produced by PT. MRT in CAD format. The digitization was done from floor to floor to all physical rooms according to the ABD plan and the ABD vertical sections using Autodesk Revit 2019 (Figure 2). The 3D geometry of walls for each floor was created by digitizing corner points of walls seen from the ABD vertical sections. The 3D geometry of the floor and ceiling for each floor was created by digitizing the top view of the ABD plan. The height between top points (ceiling) and low points (floor) for each room was determined by extruding the 2D geometry of the floor based on the height derived from the cross-section view. The digitization and extrusion were done to all physical spaces in the building using the ”Wall”, ”Ceiling” and ”Floor” tools in Revit. After the building reconstruction by manual digitization was finished, the data conversion was done to export 3D models originally stored as Autodesk Revit 2019 data format (*.RVT) into 3D models of

IFC 2x3 format (Figure 3). The resulted component and attributes from this conversion follow the IFC format schema (buildingSMART International 2021) .

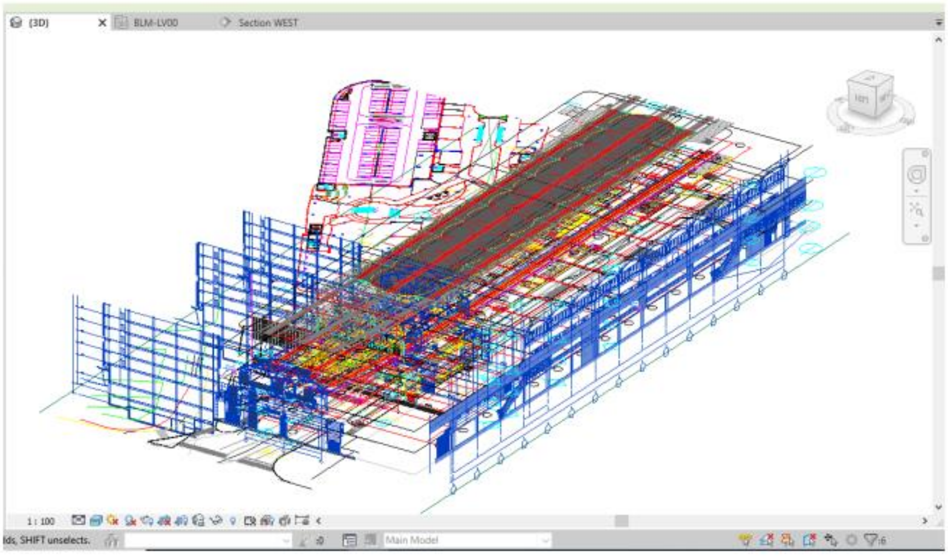


Figure 2. The ABD plans and sections of the building loaded into Revit and overlaid with the map of surrouding 2D parcels (top left) (Atunggal et al. 2020)

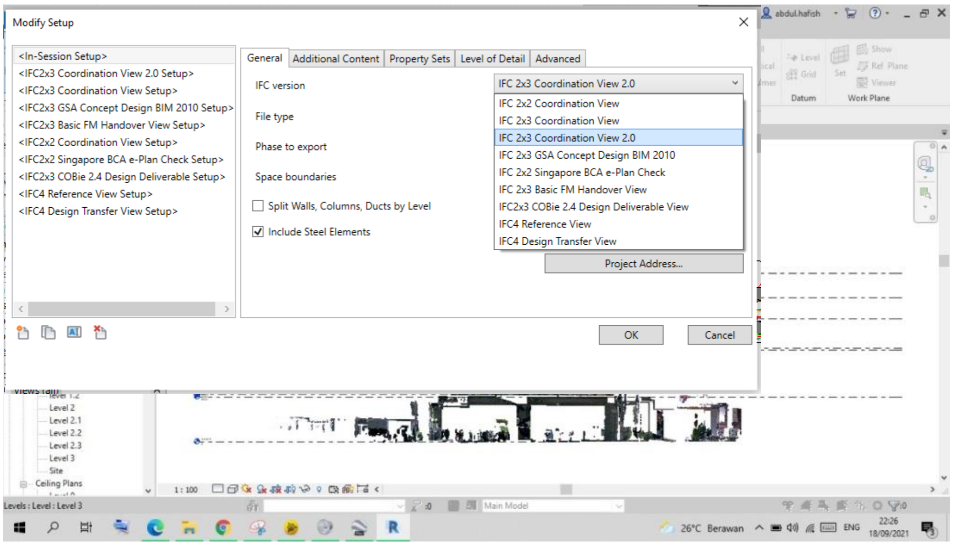


Figure 3. Options to convert the models into the IFC 2x3 format

It is worth mentioning that the IFC model of MRT terminals was not generated from 3D as-built survey as often found on BIM models. Instead, the IFC was developed from the buildings’ floor plan, which limited the modelling to some extent. Figure 4 depicts the results of BIM modelling in the IFC/BIM format.

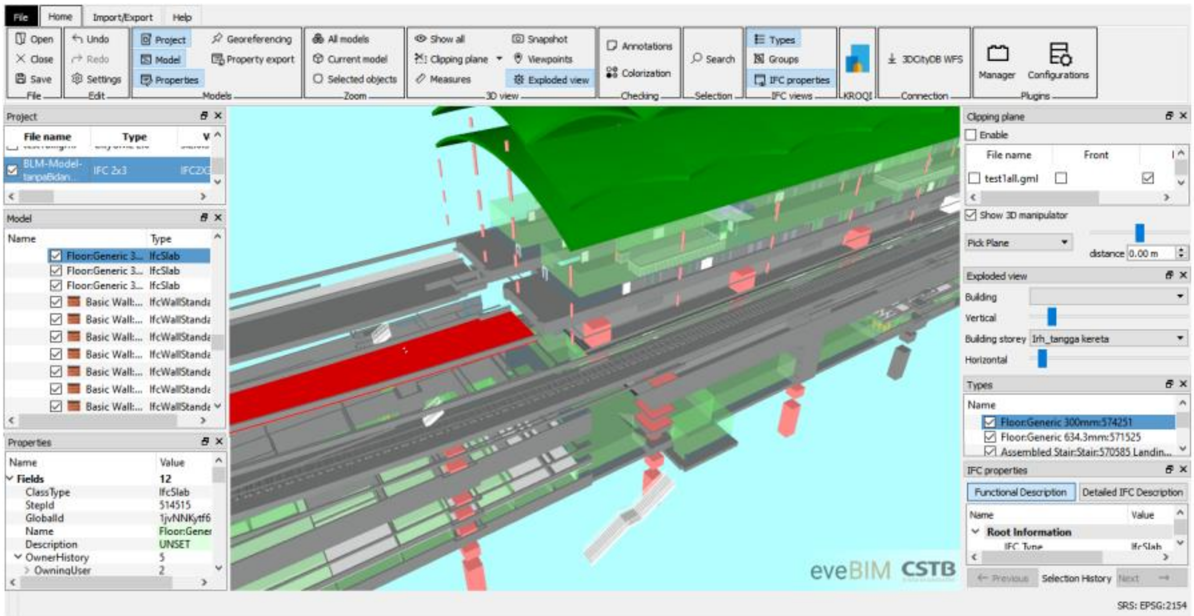


Figure 4. The resulted IFC/BIM of Blok M terminal in eveBIM (Atunggal et al. 2020)

3.3. 3D Validation

By 3D field validation, a surveyor performs the field validation survey to selected 3D units on the field. For this purpose, as also required for 2D parcel measurements, a surveyor must prepare the working map. The working map can be in the form of a 2D plan or 3D views of spatial units to be checked. In our pilot study, in addition to the parcel map, research members (acted as surveyors) used the digital version of the planimetric and cross-sections view of 3D models for conducting the field measurements. During the field validation, surveyors check the points and boundaries of 3D spaces to be registered (seen as 3D legal spaces). Using a distance meter, surveyors measure side distances and diagonal distances to gain areas and volumes (Figure 5).

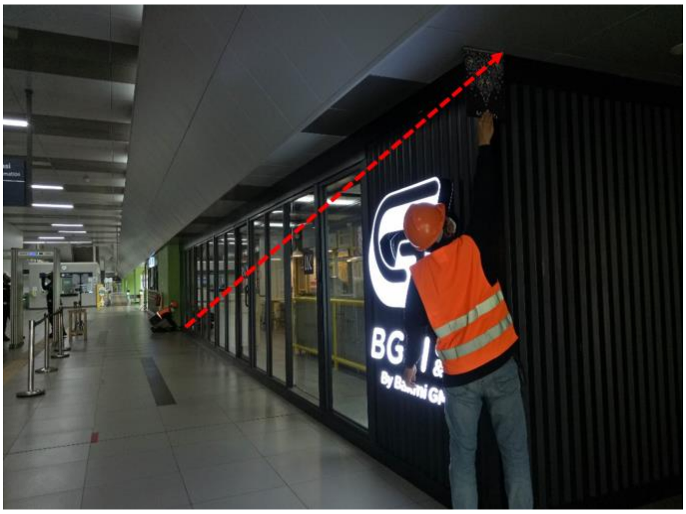


Figure 5. Measuring a diagonal distance of the wall of a unit (Atunggal et al. 2020)

After surveyors completed the survey, they assessed differences between survey and computation results. The factual areas and volumes will be compared against the areas and volumes computed from the 3D model. During field validation activities, any errors in the generated 3D model were documented to be edited straightaway on the field or later in the office. As it is required for first titling in 2D Cadastre, the results of the field validation should be documented into a measurement plan (known to surveyors as *Gambar Ukur*/GU). The digital measurement plan for 3D cadastre can be presented either in section by section or room by room, depending on the complexity of the building units (see e.g., Figure 6).

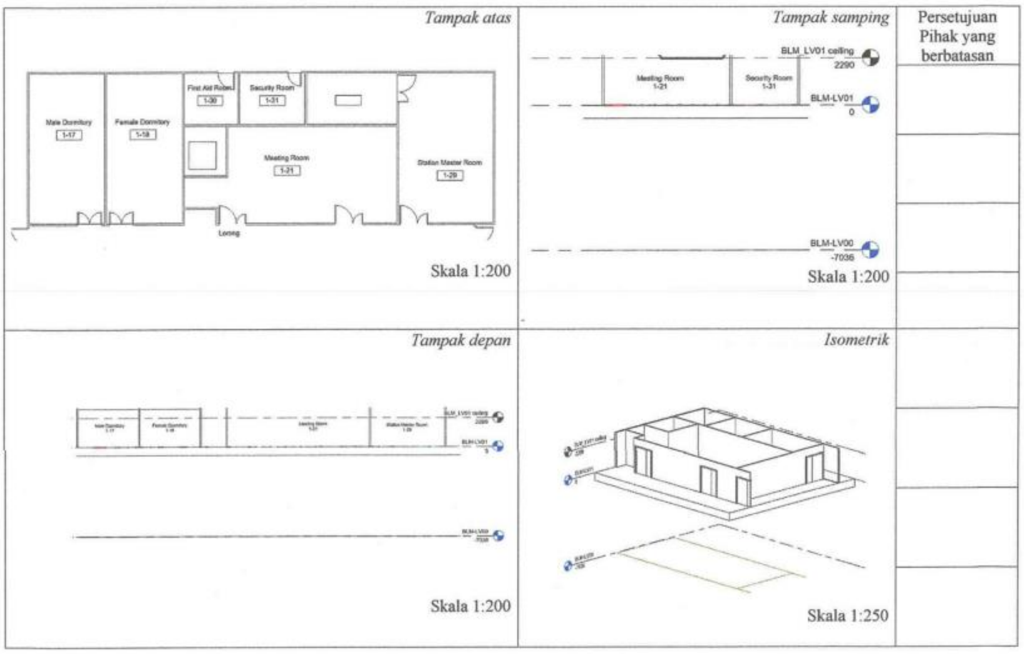


Figure 6. An example of field measurement plan (top-side-isometric-front view) and contradictory delimitation agreements, prepared for a field validation of 3D units.

In addition to representations of 3D units, the field measurement plan contains the identifiers of parties involved in 3D boundaries' delimitation. As implemented for the 2D boundary survey, person identifiers or fingerprints of boundary survey participants can be collected on the field using the surveyor mobile app like Survey Tanahku (Aditya et al. 2021).

3.4. 3D Visualization

To present the data into web visualizations, we converted 3D models of both Blok M and HI MRT terminals from IFC 2x3 format into CityGML using eveBIM. The conversion was done by selecting IfcSpace of the resulted IFC data model. The version that we used in this pilot study was CityGML version 2.0. At the time we finished the study, the available version for CityGML was CityGML 2.0. In addition to the eveBIM, some alternative software can convert IFC into CityGML format data, including QGIS, ArcGIS, Safe software FME, Autodesk Infraworks and so forth (Noardo et al. 2021). To visualize the 3D legal spaces, this study used eveBIM and Sketchup City Editor to produce CityGML building type with multisurface representations by selecting each wall as data input for data conversion from IFC to CityGML. Sketchup City Editor can be used to determine specific surfaces in the model for data conversion (e.g., selecting IFC surfaces to be converted as room classes of CityGML).

After the data was converted, the CityGML 2.0 format validation was executed to ensure the validity of the system coordinates, the geometry content and the semantic information of the converted geometry. For this study, the authors utilize open-source software (i.e., CityGML Tools and val3dity) to validate the files resulted from the conversion (Figure 7). We found more than 600 errors after the conversion. Common errors were on the coordinate system definition, ID and semantic mismatch of the MRT 3D models. To exemplify, in our case, the CityGML converter did not recognize TM-3o, the coordinate system being used for the Indonesian cadastral mapping system (i.e. the study area is at 48.2 zone of TM-3º).

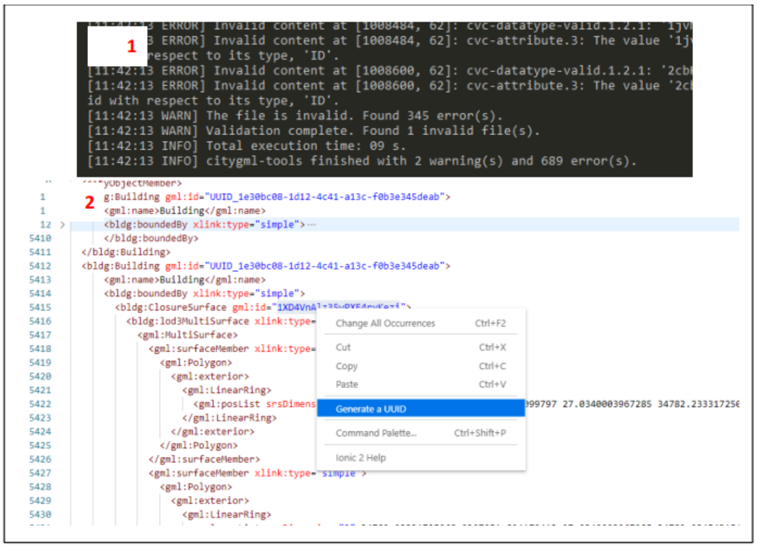


Figure 7. The CityGML format validation with CityGML Tools (1) errors found (2) the editing process to fix errors (Atunggal et al. 2020)

In fact, it is also possible to develop a web-based visualization for the IFC model (e.g., using (Viegas 2021)). However, the authors are currently investigating the pipelines for 3D Tiles as format for visualization, which provides many benefits when dealing with large datasets. 3D Tiles could be obtained by converting a 3D data format such as CityGML, for example, through platforms such as Cesium Ion (Cesium 2021) as per the previous study conducted by the authors (Aditya et al. 2020). The authors are aware that similar options are also available for the IFC format, but this investigation is out of the scope of this pilot study. The results of data modelling and field validation were visualized as a tileset on the Teria Map. For this option, the 3D tiles from CityGML were prepared as binary GLTF (.glb) using Cesium Ion.

4. RESULTS

The reconstruction of 3D models of two MRT terminals and the preparation of the working map for field validation could be finished in a month. If the team received ABD plans and sections in the CAD files that were directly generated from 3D as-built survey, the development of IFC 3D models would have been faster. Additional field photos and videos were undertaken to help accelerate the reconstruction of floors, walls, ceilings and room interiors using ABD plans and sections (Figure 7). The results of 3D models were integrated with existing 2D parcels, which were then exported and taken to the field to validate distances, areas and volumes of individual units.

The field check were done to 35 units of rooms in the HI station and 48 units of rooms in the Blok M station. These units have different types of uses, e.g. storage and auxillary rooms, service rooms, commercial rooms, office rooms and pubic spaces. The room areas were ranging from 4 m^2 to 160 m^2 with the volumes from 14 m^3 to 999 m^3. Many of these rooms are typical rooms with possible 3D variations, from simple to complicated 3D variations. During the field check, we sampled both simple and complicated units. For example, typical commercial rooms had floor areas of 23 m^2 and 33 m^2.Both total stations and distance meter were used to verify the 3D models (thus to verify the actual spaces typically applied for 3D rights as well). From the field check to the total of 83 units in two terminal stations, it was found that the distortion of 3D model areas and volumes in average was no more than 2% from the field check. There were eight (4) rooms exceeded 1 m^2 difference in floorareas, 5 in HI terminal and 3 in Blok M terminal. In general, the generated 3D models from ABD plans and sections were accurate, however some 3D units were not correctly represented as the height determination from the floor to ceiling in some rooms were wrong. This can be the result either the ABD section is incomplete or the were some changes after the ABD creation.

All the changes and distortions on the field were marked and documented in the field measuremnet plan for further processing. This can be important notes for further processing of 3D spaces to be registered. After the field validation was completed, the physical data, the ownership boundary and the attrbutes of owneship can be entered into the registration system.

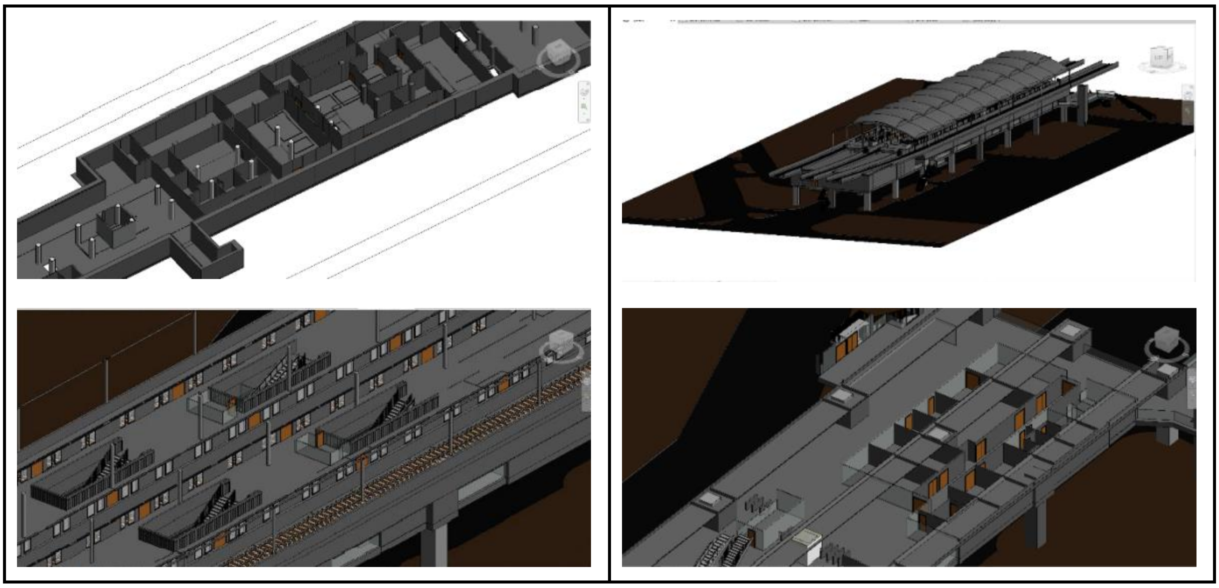


Figure 8. Reconstruction of 3D Models from As-Built Drawing (ABD) data of the MRT Stations of HI Station (left) and Blok M Station (right) (Atunggal et al. 2020).

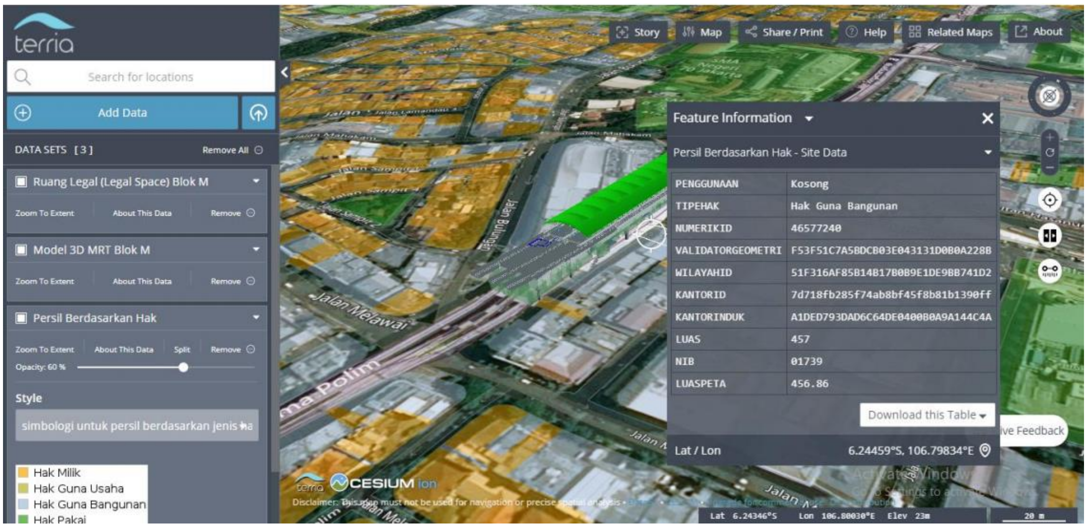


Figure 9. A visualization platform for displaying field validation; three layers can be activated (left panel from top to below): physical 3D model of Blok M station, legal spaces of Blok M and 2D parcels with rights

In this pilot study, we only focused to present the spatial data of physical and legal of 3D units. The visualization of the Blok M terminal station was done using TeriaJS as the visualization platform and Cesium to provide 3D Tiles to Teria map. There are three layers to display in Teria map: the physical 3D model, the legal space (3D parcel) and the 2D parcel (Figure 9). As discussed earlier in Section 2, the legal spaces were gained by previous editing which comprises of selecting walls, floors and ceilings for each unit as IFCSpace, which subsequently converted to CityGML BuildingRoom using EveBIM. The legal spaces can be activated to support the visual check of 3D units (Figure 10). In the pilot study, the HI terminal was not presented into Teria map.

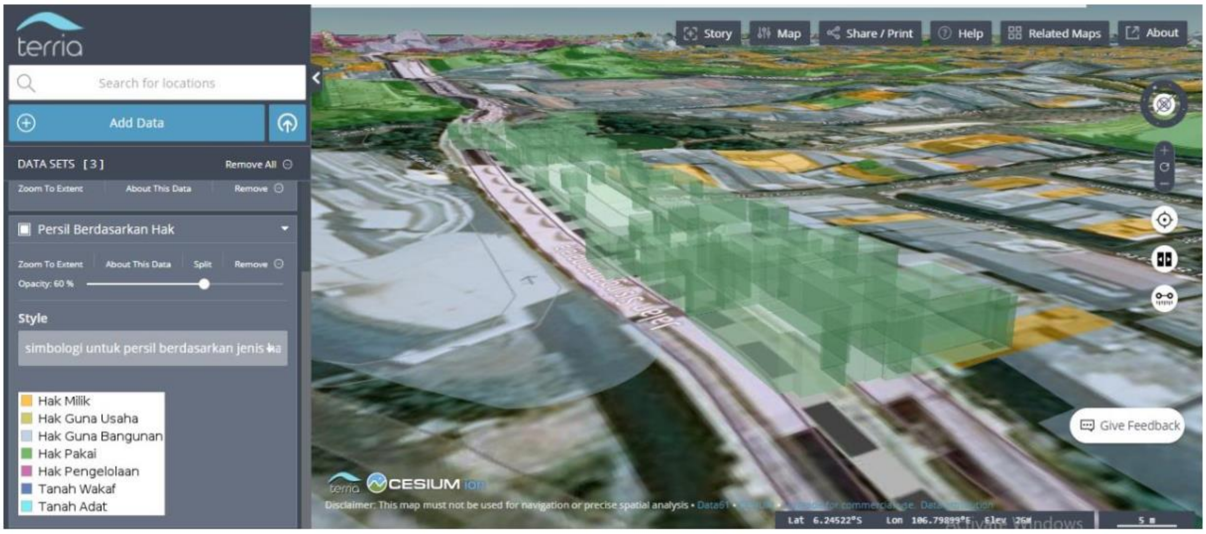


Figure 10. Legal spaces of MRT terminal at Blok M and its surrounding 2D parcels with rights (Atunggal et al. 2020)

5. DISCUSSION

According to the new regulation, once the 3D boundary verification (including height conformance to the spatial plan) is finished, the registration of 3D rights can be processed. Prerequisites for the registration include construction permits and spatial plan approval (in case the units are above or below specific heights regulated by the spatial plans), which the developer operator should provide. The authors realized that more investigations are needed on some issues (e.g., conformance to 3D spatial plans) regarding the technical and legal implementation of 3D cadastre in Indonesia.

The ownership of 3D units of terminals will be either with a right to build (HGB) or a right to use (HP), depending on the proposed use activities by the operator and the tenants. During the pilot study, the conceptual workflow and the systems (e.g., handling the typical operator or developr construction data for efficient processing in 3D registration, the field measurement plan and documentation) were developed. The study results have been used as one of core materials to develop guidelines for implementing survey and mapping activities for the 3D cadastre initial registration by the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency (MoASP/BPN) to be published at the end of 2021.

The choice to use the IFC format for 3D modelling seems appropriate considering the popularity of the format for developers/operators and the mandate by the ministry that regulates buildings and infrastructures (i.e., Ministry of Public Works). The new building models are directed to support the level 5 to level of BIM implementations as mandated by the Government regulation number 16/2021. Previously, in 2018, this ministry has required that developers of government or state buildings utilize BIM technology in its planning, construction and management. This study presented the 3D physical and legal spaces using 3D Tiles created from CityGML. This approach was chosen to follow a similar workflow implemented for registering 2D parcels in land offices, i.e. surveying and mapping in CAD while boundaries and their corresponding rights in geometries of simple features. The study has not delved into the comparison between 3D Tiles from CityGML and 3D Tiles from IFC format in terms of efficiency and effectiveness, accustomed to existing cadastral databases of the country. An alternative for creating 3D tiles from the IFC format has also been proposed and tested (Chen et al. 2018; Olfat et al. 2021). For this reason, the following research should address this issue to find the answer on the compatibility of both options to be integrated with the national cadastral databases system, which currently is only focusing on 2D parcels.

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BIOGRAPHICAL NOTES

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