

Level of Detail Analysis for Property and Building Information Modelling (BIM) Integration

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Abstract

The construction is one of the most profitable sectors in Indonesia, especially for government projects. Technological developments also made the construction sector develop. One of these developments is the introduction of Building Information Modelling (BIM) for all stages of construction, starting from planning, design, construction, monitoring, and maintenance. BIM could accommodate all these processes by providing geometric data and information that is reliable and easily processed or updated. In BIM, there is spatial resolution known as Level of Detail (LOD). The level of detail is a level for point clouds density in representing an object. Each level of detail can be utilized as needed in representing objects. In this research, BIM models will be formed with several levels of detail. The BIM model will describe the room and property inside it. Then the model will be analyzed so that the most effective level of detail can be determined for property.

1. Introduction

Acceleration of development in the facilities and infrastructure sector is a top priority in the development plan in Indonesia because facilities and infrastructure are effects to the growth speed up of all aspects both directly and indirectly. The advance of infrastructure development requires the support of information system technology, from the side of procurement, planning, implementation, supervision to operation, and maintenance (Supriyatna, 2010). One step to speeding it up is must be supported by smart methods in the process of infrastructure development by implementing digital technology. Digital technology can be multiple solutions to facilitate the acquisition, processing, and selection of information related to assets and facilities that make it easier for model development and estimation (Araszkiwicz, 2017). One of which is Building Information Modelling (BIM). Building Information Modelling is an approach to building design, construction, and management. The BIM model can be used during project work because changing the design will automatically update all data collected (BIM Lecture Notes, 2015). BIM is supporting project design, schedules, and other information in a well-coordinated manner (FGDC, 2002). Also, BIM has also described objects and/or information they contain in two dimensions or three dimensions (Eastman et al., 2011).

The spatial information is needed to implement the acceleration. Because that information can

describe plans for building a facility and infrastructure, making the process of updating as-built drawings easier and for maintenance support when it has been established. BIM is a method that is useful in the development field because it can integrate and share information models related to the life-cycle assets of a building (Kivits and Furneaux, 2013). For several years, requesting accurate BIM from a construction site has increased. This condition is driven by the fact that BIM was able to produce the most accurate digital models for the Architecture, Construction, and Engineering (ACE) industry (Eastman et al., 2011). As-built drawings in the form of As-built BIM's are needed with a level of accuracy or Level-of-detail (LOD) 300 (BIMFORUM, 2013) and an accuracy level at Level or Accuracy (LOA) 30 (BIMFORUM, 2013 and FGDC, 2002). To produce this data, it requires a high-resolution point cloud.

The terrestrial measurement using lasers has developed rapidly—this technique producing three-dimensional information in the form of arrays with density in millimeters because of their observation point by point. In this study, BIM models will be formed for properties with various types of LOD values. The results of the BIM model obtained will be compared visually and geometrically, which will then be analyzed for their suitability.

2. Literature Review

A literature review is about the concept of level of detail, building information modeling, terrestrial laser scanner.

2.1 Level of Detail

Level of Detail (LOD) defined states the degree of completeness of the geometry and information it contains or as known as Level of Development (BIMFORUM, 2013). However, in this paper, the definition of LOD used is Level of Detail, which states the point cloud density that describes a property. There are several agreed LOD values (BIMFORUM, 2013):

- a. LOD 100. Models formed from this LOD are represented or modeled with ubiquitous symbols.
- b. LOD 200. Modeled using a general system with an approach to the value of a quantity, size, location, and orientation of the property.
- c. LOD 300. Modeled using a system that is more specific than LOD 200 with absolute values for quantity, size, location, and orientation of the property.
- d. LOD 350. The resulting model is the same as the model on the LOD 300 but can be connected to the system of other properties.
- e. LOD 400. The LOD 300 model has detailed information regarding the manufacture, collection, and installation.
- f. LOD 500. The resulting model has the value of quantity, size, location and orientation of the property and the information has been verified

The LOD used dramatically influences the model produced; the selection of LOD used must consider the purpose of the model. Some of the objectives of the model are conceptual design, visualization, site planning, BIM modeling, development coordination, and structural design (Graphisoft, 2015). Besides, for modeling, it is necessary to pay attention to the complexity of property, software, and hardware used (Graphisoft, 2015).

The purpose of the model generated from this paper is BIM modeling with various LOD values. The BIM model provides detailed additional information where the information can be traced, improved, and reported (Kelly et al., 2013). BIM modeling has the following characteristics (Graphisoft, 2015):

- All properties must be modeled and have information

- The results of the calculation of the property elements must be correct
- The density of the model must be following the needs of the drawing

2.2 Building Information Modelling

BIM is a digital modeling project that has and combines information from various sources and can be developed at all stages of the project (Mordue et al., 2016). There are several kinds of acquisition data methods for building BIM models, namely (Randall, 2013):

1. Manual method. Modeling with this method uses a measuring tape to measure the room and the property, and then it described as a model. This method is very effective for reducing costs, but the accuracy of geometry's model is not satisfied.
2. Near Distance Photogrammetric Methods. The accuracy of the model generated from this method depends on the data retrieval methodology, the quality of the camera, and the software used.
3. Laser Scanner Method. Recorded millions of point cloud of the room/property as the observation's object to build the BIM model. The distance and geometry accuracy of this model is better than the other two methods but required a higher cost for sure.

Because a good geometry value is needed to analyze each LOD, this research will use point cloud data generated by measurements using Terrestrial Laser Scanning (TLS). The results of measurements using TLS will be the basis for comparing several LODs that are applied to the model. Terrestrial Laser Scanning is a measurement tool that uses lasers to record room/property data (Quintero et al., 2008).

2.3 Terrestrial Laser Scanner

The laser as an acronym of Light Amplification by Stimulated Emission of Radiation is a technology that emits visible light with a very narrow sweep area and low divergence that generated the short wavelength so the energy that produced can be significant (Quintero et al., 2008). Measurements using TLS have the principle that the scanner records two events in the same time frame or commonly known as time-based measurements (Quintero et al., 2008).

In general, time-based measurements classified into two groups, phase-based and pulse-based measurements (Quintero et al., 2008). Pulse-based measurement emitted and transmitted pulses of light waves through a particular medium at a constant

speed. Then after it hits targets, it will be reflected and returned to the receiver (Quintero et al., 2008). The emission time when the wave is transmitted and reflected on returning is recorded. Using equation (1) the distance between the transmitter and the target will be calculated (Quintero et al., 2008):

$$d = \frac{c * \Delta t}{2}$$

Equation 1

d : distance between object and sensor (m), c : wave velocity (m/s), t : recorded time (s)

Whereas to determine the position using TLS is the data angles and distance of the results of the measure against the target (Reshetyuk, 2009). The distance can be obtained based on calculations using equation (1), whereas angles are derived from the measurement results using the Angle Measuring System (AMS) found in TLS (Reshetyuk, 2009). AMS determines changes and movements of the tool horizontally and vertically so that angles are then used as an azimuth angle to determine the position of the point against TLS with the polar method (Reshetyuk, 2009), can be seen in Figure 1 (Setiawan, 2016).

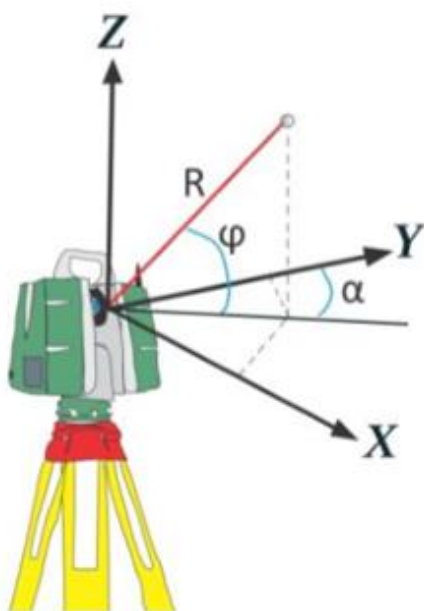


Figure 1: Positioning illustration using TLS

Positions generated from TLS measurements can be calculated through equations (2) to (4) for each component X, Y, and Z (Reshetyuk, 2009):

$$X = d * \sin \varphi * \cos \alpha$$

Equation 2

$$Y = d * \cos \varphi * \cos \alpha$$

Equation 3

$$Z = d * \sin \varphi$$

Equation 4

d : distance between object and property (m), φ : the oblique angle formed from between the horizontal plane of the sensor and the object, α : azimuth between the tools and object (where the Y-axis leads to North)

Point clouds are dots of millions of recordings for one scan using TLS. The density of these point clouds shows the spatial resolution of the tool used (Reshetyuk, 2009). In Figure 2, it can be seen that the difference in recording results uses low and high spatial resolution (Setiawan, 2016). It can be seen that the higher the spatial resolution, the more closely the scanning results point so that it is more representative of the real property. The lower the spatial resolution, the fewer the scan points (Reshetyuk, 2009). This spatial resolution will affect the model produced for each LOD value.

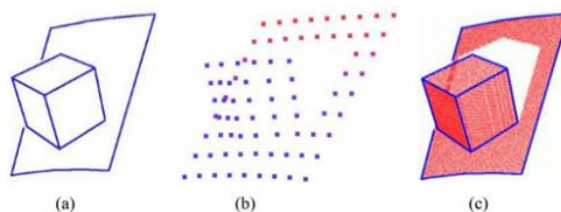


Figure 2: (a) Real property form, (b) Low-resolution result scanning, (c) High-resolution result scanning

As the measurements postulate, it cannot be denied that each measurement has errors with no exception for measures using TLS. There are some sources of errors in the TLS tool (Quintero et al., 2008):

- Error on the device. These errors include laser beam propagation errors, property edge identification errors, distance uncertainty, angular uncertainty, and coordinate axis errors in TLS.
- Error due to property. Errors occur due to differences in material and color-forming properties that affect the signal reflected by the property. Very dark property surfaces absorb more of the light spectrum, causing weak reflected signals, reducing the level of accuracy of the point position. Meanwhile,

for properties that have high reflectivity, they can indicate other surfaces that are not the surface of the property so that there is an error in the recorded property.

- Environmental errors. Because TLS emits light waves, the conditions of air temperature, atmospheric conditions, radiation, and interference due to shocks will affect the accuracy of the measurement results.
- Methodological error. Errors are originating from humans or TLS users. Generally, this error occurs because of an error in choosing a survey method or a lack of user experience in utilizing TLS technology.

In some cases of large-dimensional property recording by TLS, scanning several times is needed to record the entire property. Scanning the position of a property is determined by the coordinate system of the tool, so it is necessary to combine several scan positions into a global or local coordinate system. This merging technique referred to registration that can be done directly during scanning where TLS coordinates are bound to global coordinates and indirectly where local coordinates are used (Quintero et al., 2008). Indirect registration techniques are divided into (Quintero et al., 2008):

- Target to target registration. This technique requires a minimum of three targets from two results of scanning to complete six transformation parameters (three translation parameters and three rotation parameters), and to minimize errors using the least square, more target numbers are required.
- Cloud to cloud registration. The technique requires the presence of two/more with the scan area overlaps about 30-40%. This registration technique uses the Iterative Closed Point (ICP) algorithm. In this registration technique, the user will manually select at least three corresponding points. The selected three correspondence points will never be the same with each other; the ICP algorithm will check the iterative distance between point clouds and estimate changes to combine the two scan results to produce a minimum error.

3. The Material and Method

This section is about material that is used in this research and the method to process the material. In

this study, the property used as the investigation was a room on the second floor of Institute Technology Bandung (ITB) student dormitories located in the ITB Jatiningor neighborhood. This room scanned several times based on the spatial resolution available on the TLS tool; this result is then defined in several LOD values.

3.1 Data Acquisition

Control Point: The method of measuring control points is done by GNSS RTK (Real Time Kinematics) and Electronic Total Station (ETS). The location of the control point is shown in Figure 3. BM1 and BM2 points are in an open area, so the measurements can be made using GNSS-RTK to measure the coordinate. Because the object observation is inside the building and cannot be seen directly from BM1 and BM2 points, so a support point is created inside the building with the TB1 and TB2 points measured using ETS. The TB1 point is on the 1st floor, and the TB2 point is on the 2nd floor.

Property and Room Point Clouds: Point cloud data generated through a scanner by pulse-based Terrestrial Laser Scanner Topcon GLS-2000 series. There are several advantages, such as the ability of Full Dome Field-of-View (FOV) with 360° (H) and 270° (V), the automation of accurate height measurement, and the ability to time-off light to detect property (Topcon, 2018). Topcon GLS-2000 is also equipped with a 5 MP camera with a 170° viewpoint used to capture properties in the form of photos (Topcon, 2018).

3.2 Point Cloud Registration

In several countries, the standards and specifications of BIM data differ by the source, structure, and data format (Patacas et al., 2015). So the raw data of BIM cannot be directly processed on point cloud processing software. The raw data must be converted into the standard format using Magnet Collage software. Point clouds that converted into .e57 format do not change the measurement results, so it still contains noise. Noise is data that should be discarded because it is not needed. In this study, the noise defined as point clouds that are not related to properties, such as trees and other buildings that are recorded during data acquisition. The process for removing noise from data is called cleaning or filtering. Then proceed with the cloud to cloud registration process, which is a technique of combining several scan results (Bagaskara, 2017).



Figure 3: ● Measurement points using GNSS-RTK ● Measurement points using ETS

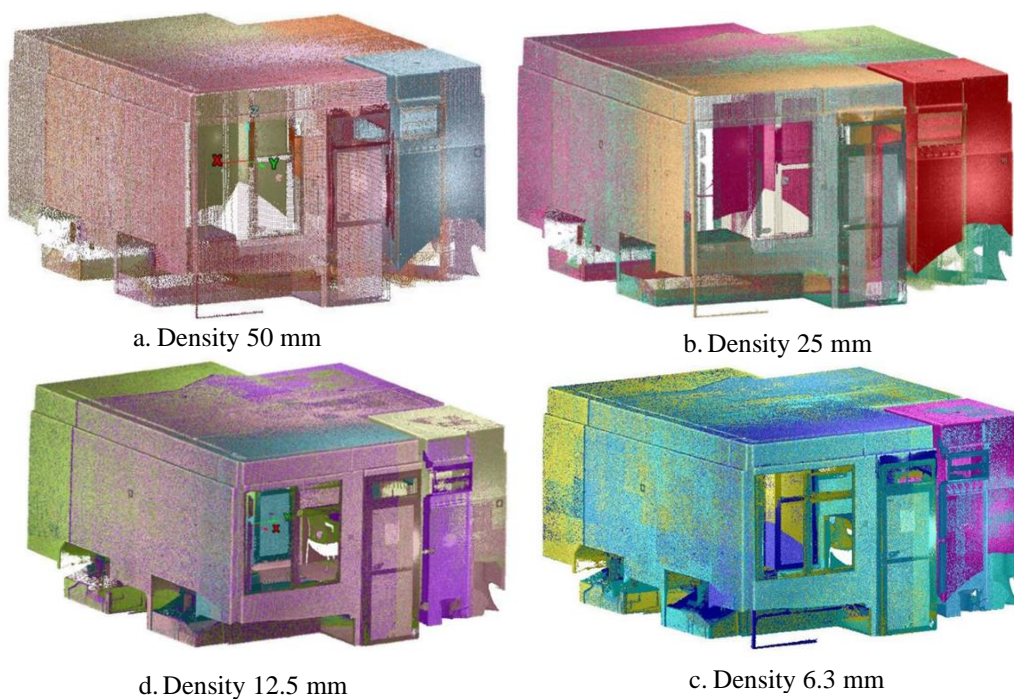


Figure 4: Registration result of point clouds

Registration Manual: It is the first step to bringing together two different scanning results that have different orientations. The difference in orientation is because the coordinates of point clouds are bound to the local TLS coordinate system, so when there is a transfer of the observation station, the TLS coordinate system will experience a change of orientation. The thing to do at this stage is to choose one scan result as a reference. Then by using tools translation and rotation on Maptek, a manual transfer is done so that the two scan results are united and have the same orientation or approach. In

this stage, the overlapping of the two scan results will combine.

Global Registration: The next step is the global registration. At this stage, both scan results must have been in the same orientation to carry out the global registration process. Global registration uses the Iterative Closest Point (ICP) algorithm to formed point clouds are better and increasingly represent the observed property. The quality of the registration results can be assessed visually and by the value of Root Mean Square Error (RMSE).

Visual quality is considered good if all scanning cloud points from each observation station have merged and formed the observed property. While for the RMSE, the smaller its value, the better of registration quality. If the quality of registration results is not as expected, it is necessary to repeat the registration procedure so that the quality of the desired registration results is achieved.

The registration and filtering process is using data with .e57 format. This data is processed using Maptek i-Site Studio 7.0. After the registration process has been successful, the registration point clouds are exported into the .las format, which is then converted into the .rcp format using Autodesk Recap 360 so that data can be processed in the Autodesk Revit software. Autodesk Recap 360 software is used to separate point cloud of room data and property data. Therefore, the point cloud of the room is generated without properties in the (*.rcp) file format.

3.3 Creating a BIM Model

Point clouds from the registration with the .rcp format are used as a framework for making BIM using Autodesk Revit 2016 (student version). In Autodesk Revit, two menus are used, namely project and family. Family is defined as a BIM constituent unit with unique characteristics. In this study, the family is property or facilities that are in the room like tables, chairs, mattresses, etc. The project is a combination of several families that form BIM as a whole. In this research, the building of BIM begins with creating a room model using the room cloud point in the .rcp format using the Revit project. Whereas to model properties using the point clouds property in the .rcp format on Revit family. Then do the merging of the room model and property model using the Revit project.

Building a room model done on the Revit project is the process of creating the floor, walls, and roof of the room using the room's point clouds. At this stage, the component specifications are made. Specifications are detailed descriptions of components such as type of constituent material, component dimensions, component structure, color, and so on.

Meanwhile, in the process of building property or facilities using Revit family is the process of creating room building units such as windows, doors, tables, chairs, water closets, and mattresses. Two methods can be done to make a 3D model of the property. The first method is to select the property template provided by Revit then change the dimensions to fit the actual conditions. For example, Revit delivers a template for a family table with

dimensions (length, width, and height) that are different from the table in the room. Therefore by using the Edit Family tool, the user changes the dimensions of the table template by entering the actual length, height, and width of the table. One disadvantage of this method is that the shape of the property being modeled will only by following the real conditions if the template contained in Revit; if not, then the property model can only display similarities in dimensions with the original property.

The second method is to create a new family by manually drawing on the Revit family. In this method, the user determines all the property building parameters so that the shape and dimensions are by the actual property conditions. This method is done by manually describing properties. The property model must be as close as possible to real terms. For this reason, the first method is used to compile a window, door, and water closet model because there are templates that match the real conditions. At the same time, other facilities such as tables, mattresses, chairs are made using the second method.

Combining both models of room and property is done on the Revit project with compiling process the family that has been made to the room model, using data point clouds so that a 3D model of the room is produced. Because BIM is a combination of 3D models and information from buildings, it is necessary to display information from the 3D model of the room using Autodesk Revit. The information on BIM is displayed in the database form and can be modified as needed. Using an additional program Revit DB-Link, the information databases can export and import so it can be read or modified in other software such as Microsoft Excel, Microsoft Access, MySQL, and so on.

4. Results and Discussion

Point cloud processing produces a three-dimensional (3D) model of the room. The registration results show that there are no scan results that intersect each other, and the property of the room modeled perfectly, meaning the quality of the point clouds registration results is good visually. Visually, the results of the registration with density 50 mm, 25 mm, and 12.5 mm will display the same object shape with a density of 6.3 mm, meaning that the quality of the results of visual registration of all densities is good, can be seen in Figure 4. The scanning point for those various densities is the same, and the distance between sensor and object below 10m so the registration result will be very similar. Quantitatively the differences between RMSE are too low, following Table 1.

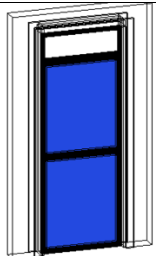
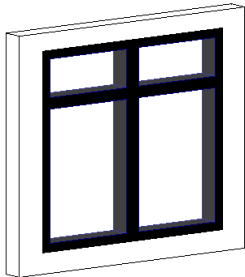
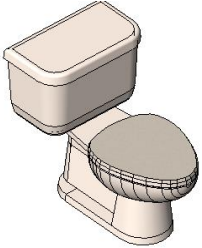
Table 1: RMSE of point clouds registration


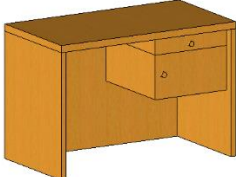
Density	RMSE Value
50 mm	0.002 m
25 mm	0.002 m
12.5 mm	0.001 m
6.3 mm	0.001 m

Table 2: Measurement value using mitband, the result of registration and its deviation

Object	Mitband Measurement (m)	The measurement from registration (m)			
		50 mm deviation	25 mm deviation	12.5 mm deviation	6.3 mm deviation
Width of Window	1.403	1.401 -0.002	1.406 0.003	1.402 -0.001	1.405 0.002
Width of Wardrobe	0.466	0.467 -0.001	0.465 0.006	0.467 0.001	0.467 0.001
Width of Bed	0.806	0.809 0.001	0.803 -0.001	0.805 0.001	0.805 0.001
Height of Wardrobe	1.801	1.800 -0.001	1.805 0.004	1.803 0.002	1.802 0.001
Width of Restroom Wall	0.145	0.144 -0.003	0.151 -0.003	0.146 -0.001	0.146 -0.001

Table 3: BIM Model and LOD 200 Specifications

Property	BIM Model	Specification for LOD 200
Door		<ul style="list-style-type: none"> <input checked="" type="checkbox"/> Generic wall objects separated by type of material <input checked="" type="checkbox"/> Approximate overall wall thickness represented by a single assembly. <input checked="" type="checkbox"/> Layouts, locations, heights, and elevation profiles are still flexible.
Window		<ul style="list-style-type: none"> <input checked="" type="checkbox"/> Generic wall objects separated by type of material <input checked="" type="checkbox"/> Approximate overall wall thickness represented by a single assembly. <input checked="" type="checkbox"/> Layouts, locations, heights, and elevation profiles are still flexible.
Toilet		<ul style="list-style-type: none"> <input checked="" type="checkbox"/> Schematic layout with approximate size, shape, and location of mains and risers; <input checked="" type="checkbox"/> Shaft requirements modeled;

Chair		<input checked="" type="checkbox"/> Generic model elements with approximate nominal size. <input checked="" type="checkbox"/> Placement and quantity remain flexible.
Table		<input checked="" type="checkbox"/> Generic model elements with approximate nominal size. <input checked="" type="checkbox"/> Placement and quantity remain flexible.

The similarity is also applied to the property, the deviation between registration results compared to the measurement using iron measurement tape following Table 2. The geometry quality based on the deviation between the registration point clouds and the value of the direct measurement. The greater the deviation value, the worse the geometry quality. On the contrary, the smaller the deviation, the better the quality of the geometry. Table 2 shows that the magnitude of the deviation is quite small (millimeters). This information indicates that the geometry quality of the point cloud data from TLS measurements from each density in the room and property is good and can be used as a framework for making three dimension models (3D) on BIM. The density of the points that make up the BIM model must be accurately and correctly recorded (Saptari et al., 2017). In this research, the BIM model will be built from point cloud density 12.5 mm and follow LOD 200 specification (Zhan et al., 2014, BIMFORUM, 2018), which could be seen in Table 3.

Following LOD 200 Specification from BIMForum, the result is fulfilled almost all of those specifications for classifying the property. Meanwhile, the LOD 100 gave not as well as LOD 200 result, and LOD 300 requires more space than LOD 200, so to efficient space without decreasing the quality of the model, the LOD 200 is highly recommended.

5. Conclusion

BIM will become a technology that will be applied to the entire process in Architecture, Construction, and Engineering (ACE) industry from the design stage to management the buildings or projects (Ciribini et al., 2015). However, to optimize the use of BIM is needed high accuracy of information and geometry (Zhan et al., 2014). It depends on the complexity of the object, and it will affect the measurement time and data storage requirement.

Choosing the right LOD will greatly answer these two things. From this study, we can see the LOD 200 is recommended for modeling property. And the density of points cloud gave a similar result when the distance is short.

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