3D SURVEYING, MODELING AND GEO-INFORMATION SYSTEM OF THE NEW CAMPUS OF ITB-INDONESIA

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ABSTRACT:

The new campus of ITB-Indonesia, which is located at Jatinangor, requires good facilities and infrastructures to supporting all of campus activities. Those can not be separated from procurement and maintenance activities. Technology for procurement and maintenance of facilities and infrastructures –based computer (information system)– has been known as Building Information Modeling (BIM). Nowadays, that technology is more affordable with some of free software that easy to use and tailored to user needs. BIM has some disadvantages and it requires other technologies to complete it, namely Geographic Information System (GIS). BIM and GIS require surveying data to visualized landscape and buildings on Jatinangor ITB campus. This paper presents the on-going of an internal service program conducted by the researcher, academic staff and students for the university. The program including 3D surveying to support the data requirements for 3D modeling of buildings in CityGML and Industry Foundation Classes (IFC) data model. The entire 3D surveying will produce point clouds that can be used to make 3D model. The 3D modeling is divided into low and high levels of detail modeling. The low levels model is stored in 3D CityGML database, and the high levels model including interiors is stored in BIM Server. 3D model can be used to visualized the building and site of Jatinangor ITB campus. For facility management of campus, an geo-information system is developed that can be used for planning, constructing, and maintaining Jatinangor ITB's facilities and infrastructures. The system uses openMAINT, an open source solution for the Property & Facility Management.

1. INTRODUCTION

1.1 The New Campus Of ITB-Indonesia

Bandung Institute of Technology/ Institut Teknologi Bandung (ITB) is the oldest technology-oriented university in Indonesia, established in 1920. As the multicampus, ITB has two campus locations and other plan of location. The main campus of ITB is located at Ganesa street, Bandung on about 79 hectare of land. Another campus located in Jatinangor, east of Bandung – West Java (see Figure 1). Jatinangor ITB campus was established in 2011 on the 46 hectares of land. Beside those two locations, ITB will also establish another campus in Bekasi, Cirebon, and Walini-Lembang.

Figure 1. Jatinangor ITB Campus location

The new campus of ITB, which is located at Jatinangor-Sumedang, still under development. Previously, Jatinangor ITB campus was a campus of the Winaya Mukti University, so there are a few of the existing building at this site. Now, the campus area is divided into open space and building mass, with the composition that create a sense of harmony. The open space will support rainwater collecting, which be useful as water supply. For the buildings, Jatinangor ITB campus consist of existing buildings (earlier) and new buildings. Some of the existing buildings are the main building, hall, and library. The new buildings such as Koica, general lecture building, and student dormitories. ITB multicampus programs were still developing especially in the terms of infrastructure and transportation.

Figure 2. Master plan Jatinangor ITB Campus

Figure 2 shows the master plan of Jatinangor ITB campus. Until recently, the realization of the master plan is about 50%. This master plan concept provides a comprehensive view of Jatinangor ITB Campus future development plans based on estimated growth through 2040.

As a campus, Jatinangor ITB campus requires good facilities and infrastructures to supporting all of campus activities. The facilities and infrastructures should be constructed and maintained regularly. Therefore, we need an information system that can facilitate procurement and maintainance activities, has been known as BIM. BIM can not perform some function, such as spatial analysis with geographic coordinates. BIM only uses local coordinates that varies between one object to another, so it can not be used to analyze a few things, such as wiring and plumbing are searches between buildings and spatial analysis related to air pollution, noise, and water. Because of that disadvantages, it requires other technologies to complete it, and has been known as GIS.

The paper presents experince in building of the 3D information system from data acquisition, mapping or modeling, and finally database and information system development. The main objective of this work is to build a suitable procedure for acquiring geospatial information and makes geospatial information accessible to decision makers, lectures, administration, students and visitors. Another objective in this study is to explore the capabilities of current technology software such open source GIS software to link the spatial information about the building features and utilities within the map.

The importance of campus planning is a focus in this illustrated work in order to demonstrate the effective use of 3D GIS modeling in the decision making process is a way to communicate ideas very quickly, which help to make better decisions. One technology to integrating BIM and GIS is Openmaint. Openmaint is opensource application that in this activities is integrating BIM and GIS to build information system for ITB Jatinangor.

1.2 Previous Work

In Zhang, et al. (2009), data integration (BIM & GIS) is important for effective asset management. There are various tools and methodologies exist to collect, manage, display and process the required data/information, and in this paper focuses on BIM and GIS to be used for effective asset management. That paper presents some examples of large scale of asset management, and one of them is University of Minnesota, USA.

GIS was integrated in a space management system to help the University of Minnesota's facilities information. It was discovered that location or spatial reference is considered as an organizing concept for a variety of departmental data including human resources, security, class scheduling, and inventory. To overcome the multiple database maintenance and inconsistent data, it needs consistent spatial model. Data sources must have a common identifier. The data are organized in a spatial hierarchy by 1) campus, 2) zone and or district, 3) building, 4) floor, 5) room, and 6) room detail.

Hijasi, et.al. (2010) proposed an information system that facilitates the use of BIM for geo-analysis purposes (BIM4GeoA). BIM4GeoA is a concept for combining existing open source software and open specification for efficient data management and analysis of Building Information within its boarder context. The core components are the spatial database PostgreSQL/PostGIS, the building information server, the IFC, the Google Earth 3D viewer, and the existing 3D OGC standard (KML, CityGML).

The paper writen by Dore and Murphy (2012), outlines a new approach for digitally recording cultural heritage sites from laser scan data or photogrammetric data. This approach involves 3D modelling stage and integration of the 3D model into a 3D GIS for further management and analysis. The process involves a reverse engineering solution whereby parametric objects representing architectural elements are mapped onto laser scan or photogrammetric survey data. A library of parametric architectural objects has been designed from historic manuscripts and architectural pattern books. These parametric objects were built using an embedded scripting language within the BIM software called Geometric Descriptive Language (GDL). Using this embedded scripting language, elements of procedural modelling have also been replicated to automatically combine library objects based on architectural rules and proportions. If required the position of elements can be manually refined while overlaying the automatically generated model with the original survey data. After the 3D model has been generated the next stage involves integrating the 3D model into a 3D GIS for further analysis. The international framework for 3D city modelling, CityGML has been adopted for this purpose.

1.3 Workflow

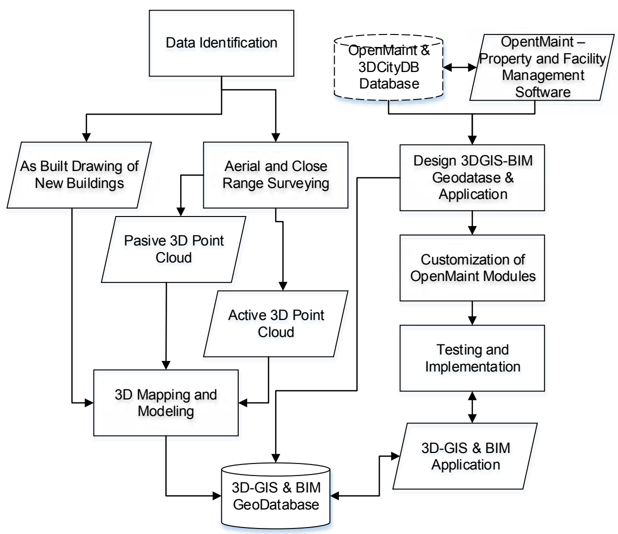

Figure 3. Workflow of developing geo-information system of ITB Jatinangor

Such as Figure 3 that has been described above, the work steps are:

(1) Data identification process, is collecting and filtering data needed. Data collected is divided into two, as built drawing for new buildings, data from aerial and terrestrial surveying for existing buildings.

(2) Aerial and terrestrial surveying required for buildings that not have as built drawings. Aerial and terrestrial surveying will generate 3D point cloud. 3D point clouds is a collection of 3D points which are characterized by spatial XYZ-coordinates and may optionally be assigned additional attributes such as intensity information, thermal information, specific properties, or any abstract information.

Based on the acquisition techniques, point cloud divided into passive and active point cloud. Passive techniques for point cloud are used for scenes with reasonable ambient lighting conditions and only collect information. Passive point cloud was collected by photogrammetry. One technique is Multi-View Stereo that focused on reconstructing a complete 3D object model from a collection of images taken from known viewpoints. Active techniques for point cloud are focused on actively manipulating the observed scene by projecting structured light patterns via emitting electromagnetic radiation in either the visible spectrum or in the form of laser light. Active point cloud was collected by laser scanner.

(3) 3D mapping and modelling process, is creating model from collected data above (the data result from step 1 and 2). Based on previous process, the collected data are as built drawing and 3D point cloud. We can extrude as build drawing to build 3D model. This process will produce a model, then stored in new 3D GIS-BIM geodatabase and processed by the new 3D GIS-BIM application.

(4) Designing 3D GIS-BIM geodatabase and application, is designing the desired geodatabase and application, based on identification data process and available software. The software use is openMAINT, free software for property and facilities management. By comparing data, openMAINT software and 3D CityDB & openMAINT database, we can determine the required application for geo-information system. This process is generate a new 3D GIS & BIM Geodatabase.

(5) Customization of openMAINT modules, is to modify the openMAINT modules according to the requirements in the designing process. And finally,

(6) Testing and implementation, is to test the new application – which is openMAINT software that has been modified. For testing and implementation, we can use sample from data that collected before. If success, it means that we have a new 3D GIS & BIM application.

2. 3D SURVEYING

2.1 Aerial & Terrestrial Close Range Photogrammetry

Based on camera position, the data acquisition is divided into aerial and terrestrial photogrammetry. Aerial photogrammetry using Unmanned Aerial Vehicle (UAV), equipped with presumes digital camera. For exterior building and landscape, it can be used a combination of aerial and terrestrial photogrammetry. And for interior, it can be used only terrestrial photogrammetry.

For interior, close range photogrammetry method using convergent and divergent of camera configuration. Acquisition data with convergent configuration was carried by surrounding the room. For exterior, the data acquisition is a combination of UAV and terrestrial photogrammetry. The terrestrial photogrammetry method is using convergent configuration camera. Angle of the images between each camera position sought is at 45^o-90^o. In addition, the object to be photographed can be seen on at least two cameras.

Two UAVs were used for aerial photo data acquisition, the first is fixed-wing UAV and the second is hexacopter UAV. The fixed-wing UAV flies over the area in a meandering flight path so it can take overlapping photographs of the entire area to get complete coverage. The hexacopter UAV is used to capture the oblique aerial images. Oblique images enable 3D modeling of objects with vertical dimensions.

The flight was performed in the end of April 2016 at Jatinangor ITB campus. 40 GCP's where marked within an area of 1200x650m (20 GCP's as Control Points, 20 GCP's as Check Points). All GCP's have been surveyed with precise geodetic devices. The standard deviation of GCP's is 3mm in planimetry and 2mm in height.

Figure 4. Dense Point Cloud from UAV- Photogrammetry

The fixed-wing UAV aerial survey was planned with following parameters in reference to the ground:
- Photo Capturing using Sony A6000 with a fixed lens 20 mm,
- Flight pattern parallel (10 lines),
- Overlap in flight direction 80%,
- Overlap across flight direction 80%,

- Ground sampling distance (GSD) 5.1cm.

The configuration results in an altitude over ground of 250m. The overlaps were reached by adjusting the UAV speed (10m/s), frequency of image acquisition (3.9Hz) and distance between neighboring flight lines (58m). The maiden flight was done following the alternating flight lines like it is common for airborne imaging flights. Thus parameters for conventional airborne flights could be used for post processing the navigation data to enhance the quality. Due to cloudy weather conditions an exposure time of 1.5ms was chosen to avoid ground smear and to prevent over- and under-saturations.

Oblique aerial images were taken from the hexachopter by means of a non-metric camera (Sony A6000, same with camera in fixed-wing UAV) equipped with a fixed lens (20mm). Images were taken with GSD ortho≈0.5cm. Close-range or terrestrial, digital photogrammetry uses photographs taken from close proximity by hand held cameras. Close-range photographs (aerial and terrestrial) can be used to create 3D models, but they are not usually used in topographical mapping. This is useful for the 3D modeling of buildings.

Thousands nadir and oblique aerial images and hundreds terrestrial images were processed by the program "Photo scan" of Agisoft. Tie points were obtained automatically and ground control points were manually measured and orientation data of the images and of the camera were calculated. The process followed by dense matching to produce dense point cloud data, digital surface model (DSM) and orthophoto. Figure 5 shows a dense point cloud data of a building in the campus.

Figure 5. Dense Point Cloud of Library Building from aerial and terrestrial Photogrammetry

2.2 Terrestrial Laser Scanner

Generally, the process for development of as-built BIM using Terrestrial Laser Scanner (TLS) is conducted through three major stages: (1) planning stage, in which the location of scans and targets are predetermined, (2) data capturing stage, which is usually done when construction is complete, and (3) data processing stage, in which scanned data are converted to 3D components through reverse engineering approaches (e.g, Akinci et al. 2006, Arayici 2007, Tang et al. 2010).

In this study, Faro TLS data acquisition is done by creating a closed polygon control point. Each of these control points placed around main building, library and the Koica building. The control points are also used as a check point for quality control of DTM and orthophoto. Sketches lying control points as shown in the Figure 6.

The TLS data acquisition is done for 10 minutes for each measurement. The distance between the points of data collection is 10m to get a more dense point cloud and cover the entire object. Each data acquisition, high-TLS is measured using a measuring tape and the position is measured using GPS geodetic receiver. At the back-sight and fore-sight, target in the form of balls mounted on control points and the Premark. Each ball must be visible from the location of the TLS.

Figure 6. TLS Station

Complex mapping of 3D object such as architectural objects required at least two scanning images to cover the complete facade area with optimum 3D modeling accuracy. For complete 3D model generation, the scanning images is needed to be registered (combined) and merged together. Existing registration method used corresponding features between the two scanned images as registration primitive and finally 3D transformation algorithm was applied to combine the images.

Figure 7 shows the dense point cloud of Library Building from TLS. Comparing visually and numerically, the point cloud from TLS is more "smooth" than dense point cloud from photogrammetry. The disadvantage is point cloud from TLS cannot cover roof top.

Figure 7. Dense Point Cloud of Library Building from TLS

Reference	Tens...	Scan 1	Scan 2
Point20	0.0717	JAT005	JAT004
Point9	0.0522	Jatinangor015	JAT002
Sphere042	0.0489	JAT005	JAT004
Sphere041	0.0400	JAT005	JAT004
Point24	0.0320	Jatinangor009	JAT005
Point23	0.0320	Jatinangor009	JAT005
Point8	0.0316	Jatinangor015	JAT002
Point24	0.0272	JAT005	JAT001
Point23	0.0272	JAT005	JAT001
Sphere031	0.0261	JAT003	JAT004
Point14	0.0243	Jatinangor014	JAT003
Point7	0.0241	Jatinangor015	JAT002
Point12	0.0233	JAT003	JAT004

Weighted Statistics

Mean:	0.0105	Deviation:	0.0155
Min:	0.0000	Max:	0.0717

Figure 8. Control Points Accuracy of TLS

Each project and point belt has an error while merging data. The average error fastening points with a standard deviation of 0.0105m 0.0155m. The error obtained by weighting between fastening points.

2.3 Secondary Data (As Built Drawing)

Usually, new buildings have as built drawing. The buildings management of office in Jatinangor-ITB Campus gives us the drawings in digital form. Spatial information is stored in several as-designed documents, including architectural and mechanical/electrical/plumbing (MEP) drawings, and process and instrumentation diagrams (P&ID).

Table 1. Types of systems and components that were designed to be included in the drawings

System	Components	Source of Spatial Information
HVAC systems	Pipe	No data
	Duct	MEP drawing
	Sensor	P&ID diagram
	Damper, valve, fan	P&ID diagram
Furniture	Table	Architectural drawing
	Chairs	Architectural drawing
	Cabinet	No data
	Ceiling light and lamp	Architectural drawing
Electronic equipment	Computer	No data
	Projector	Architectural drawing
	Camera	No data
Building element	Wall	Architectural drawing
	Door	Architectural drawing
	Window	Architectural drawing
	Ceiling	Architectural drawing

Table 1 shows the types of the systems and components that information of some components, such as pipe, computer and cabinet, is not given in any document. Second, there is no elevation or section drawing that shows the vertical position and dimension of the components. Third, during the construction, it was observed that the information from the available sources is not accurate, or the components are not built exactly as they are designed. Such deviations will be discussed in more detail in forthcoming sections. These challenges have motivated capturing of as-is conditions of the built environment as an accurate way for developing the as-built BIMs.

Figure 9. Koica building as build drawing

3. 3D MODELING

3.1 CityGML & IFC Data Model

City Geography Markup Language (CityGML) was developed in recent years as a Geographic Information System (GIS) data standard to represent the geometry and geographical information of buildings in digital 3D city models. CityGML represents the land surface and the object area being mapped. CityGML supports modeling on various Levels of Detail (LoDs) from simple box models to models with indoor or interior partitions.

There are five levels of LOD, where every level LOD will provide more detailed information (OGC, 2012). LOD 0 is a two and a half-dimensional representation of a digital terrain model (DTM). LOD 1 illustrate the block model without the roof structure. LOD 2 illustrate a 3D building has a roof structure. LOD3 show with more detailed architectural models such as the structure of the roof, doors, windows. LOD4 complement of LOD models 3 by adding structures such as interior rooms, stairways and property inside the building. CityGML models from the processing point cloud can be used in decision-support based spatial planning.

Given the demand for those indoor 3D data of buildings, however, the acquisition of such data is hard due to the fact that there are many hidden components in the building which are not able to be discovered by traditional ways such as laser scanning. In this sense, 3D models from Building Information Modeling (BIM) can serve as data source for constructing 3D GIS city models.

3D modeling is a process to mathematically represent an object or a scene in 3 dimensions using a dedicated software starting from real measurements or other information. In practice, 3D modeling can be define as the generation of structured data (e.g. polygonal mesh) starting from unstructured data (e.g. point cloud). In this study, we convert point cloud data into CityGML and IFC format. The modeling divide into 3 stage, the first is terrain modeling, the second is low level detail modeling (LOD1-LOD2) and the las it high level detail modeling (LOD3-LOD4, BIM).

3.2 Terrain Modeling

At the beginning point cloud data from nadir aerial photogrammetry were imported to this program. The first step of analysis was “point cloud” to grid conversion, parameters were defined as follows: cell size 1 m, type of aggregation – first value (which means that created grid should be a DSM). In this study ‘only z’was defined as an attribute to convert “point cloud” data to grid format. Next step was to filter DSM using DTM Filter (slope-based) option which leads to an incomplete DEM with no data pixels. For each of assessed test sites various options were chosen: for test site 1, search radius 30 and approximately terrain slope 50, and for test site 2, 20 and 30, respectively. Finally, interpolation was completed using Multilevel B-Spline Interpolation.

\Figure 10. Contour and 2D footprint building

3.3 The Low Level of Detail Modeling

BuildingReconstruction is particularly well suited for the extensive creation of building models with a level of detail of 2, which includes the attributes of roofs in the terminology of city modeling. 28 standard and transitional roof forms are supported in BuildingReconstruction. For a CityGML-compliant export, the building shell is also semantically subdivided into foundation, wall, and roof areas. Based on the modeling guidelines of SIG 3D - these thematic areas of the LoD 2 models are also referred to as solid bodies (LoD2 solid). Furthermore, additional information, such as the height of the ridge and eaves or dimensions of the roof area, which represent generic attributes in CityGML, are allocated to each building.

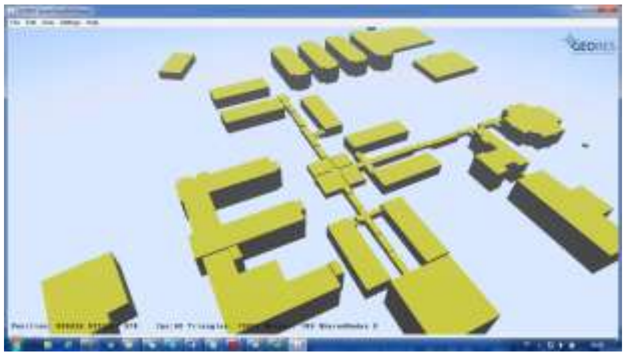

Figure 11. LOD 1

Figure 12. LOD 2

3.4 The High Level of Detail Modeling

For high level of detail modeling, we create 3D model of Library and KOICA building. Modeling needed for the construction and development process, including procurement and maintenance. There are some standards for modeling, one of them is CityGML Level of Details (LoD). In this paper, the high level of detail modeling means that create 3D model with LoD 4 CityGML standard. 3D Model with LoD 4 described detail architecture model, including interior (room, door, window, furnishing).

Data sources for modeling divided into two, as built drawing for new buildings, data from aerial and terrestrial surveying for existing buildings. Different data will make the modeling process also different.

Koica Building – As Built Drawing
First, identify the completeness of as built drawing required for modeling. It must have site plan, floor plan, elevation, section, detail structure, mechanical, electrical, and finishing drawings. As built drawing is usually a 2D image and contains a variety of information buildings. To create 3D model building, we can extrude the as built drawings by using 3D software modeling and then add some of furniture and building objects.

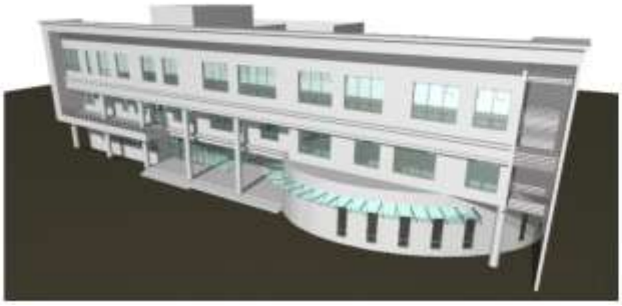

Figure 13. 3D Model of Koica Building (LOD 3)

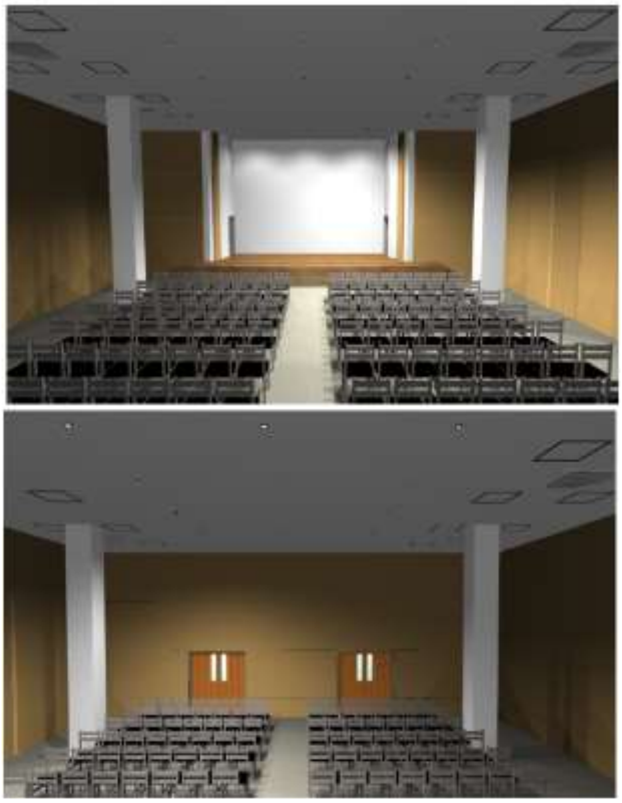

Figure 14. 3D model of Interior in Koica (Hall) (LOD 4)

Library – Point Cloud
Point cloud is a set of data points in a three-dimensional coordinate system. Different with previous method, we use two softwares for modeling. First software is used to view and collect information from point cloud data, for examples are length and height of building. And other software is used to create 3D model building, same as the first method. Then more steps involved in this method than the first method.

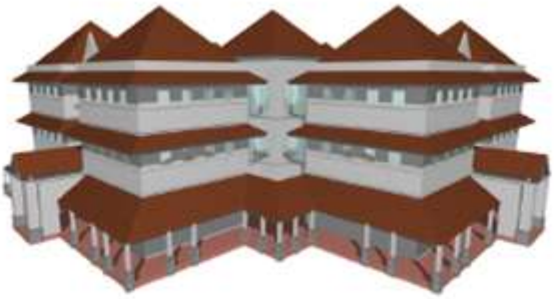

Figure 15. 3D Model of Library (LOD 3)

4. GEO-INFORMATION SYSTEM DEVELOPMENT

4.1 System Architecture

In this application, user level is divided into four levels such as Administrator, Top Level, Contractor and General User. Each level has different access rights which is Top Level can only access dashboard menu that contains summary data. Contractor can modify entire object data such as building, floor, room, etc. General User Level can only view object data and has no access right to modify data. And Administrator Level can access the entire function in the application such as create and grant user who has access the application.

Each user will be connected with the application server through the Http or Proxy from the browser (e.g. Chrome, Mozilla Firefox, and Internet Explorer). Then Application provides data from any sources such as BIM Database, Open Maint Database, 3D City Database and GIS Database. All of them could be as a server or build in separated server. In this case, we build an entire database in one server but with different port. Besides that, there is another data source that used in this application that located in cloud Service. It uses Online Spreadsheet for handling 3D City Database. All the data will be consumed by all user level with each role in this integrate application.

The central database is Open Maint Database. The Database handlings main data such as Complex, Building, Floor, Room, User, User Privilege, etc. This application will access this database directly to do modifying data activities. The Database will be related with GIS database. Each object data in this database will have one or many GIS Object data in GIS Database. Before GIS data consumed by user, all of the GIS data will be processed on map server. This application uses Geo Server as a map server. It will provide many links of map service which is data is sourced from GIS Database. Then each map service will present each object data such as building data. Therefore, application doesn't access directly into GIS Database but it will access data from GeoServer.

Another data source such as Online Spreadsheet will be saved in cloud Service. This data is used for store the visualization model of 3DCity Database. There is an export tools that will export data from 3DCity Database to a model then stored in Online Spreadsheet in cloud service. The data in Online Spreadsheet will be consumed by user in the web application in a 3D view.

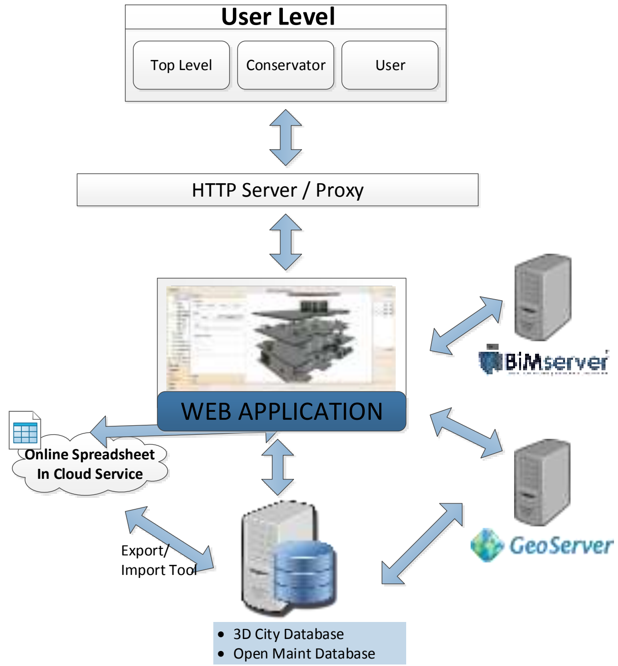

Figure 16. System Architecture

A GIS is defined as an information system that is designed to work with data referenced by spatial or geographic coordinates. Thus, a GIS is both a database system with specific capabilities for spatially referenced data, as well as a set of operations for working with the data (Zhang, 2009). GIS known as ideal tool for representing relations or situation on site (macro level) and ideal for multi-site project. BIM means working within a 3D model, via an intelligent database, that contains all information about design decision making, production of accurate construction documents, prediction of performance factors (i.e. energy consumption, load calculations, etc.), cost-estimating and design scenario planning, and construction planning (Yuan and Zizhang, 2008). BIM as an ideal tool for representing relations in building (micro level), so it used for building construction until demolition.

Integration of GIS and BIM required for supporting better facilities and infrastructures. That integration will generate more complete information and easy to use, both of macro and micro level representation. Nowadays, we can use the technology of GIS and BIM easier and cheaper with opensource application. For GIS, some of applications are Quantum GIS, PostGIS, and Grass GIS. And for BIM, such as BIM Server, xBIM, and BIM Surfer. The opensource application that is used for this activities is Openmaint.

openMAINT is an open source solution for the Property & Facility Management. It manages movable assets (installations, technical elements, furniture, etc.), the real estate (buildings, infrastructures in the area, etc.), and the related maintaining (when planned and when an issue occurs), logistic and economic activities.

openMAINT is, thanks to this choice, not only a ready-for-use standard product, it can also be configured through proper mechanisms which allow to intervene on each system element (data models, workflows, reports, dashboards, connectors, etc.).

The 3D City Database is a free 3D geo database to store, represent, and manage virtual 3D city models on top of a standard spatial relational database. The database model contains semantically rich, hierarchically structured, multi-scale urban objects facilitating complex GIS modeling and analysis tasks, far beyond visualization. The schema of the 3D City Database is based on the City Geography Markup Language (CityGML), an international standard for representing and exchanging virtual 3D city models issued by the Open Geospatial Consortium (OGC).

Figure 17. OpenMaint Architecture

4.2 Customizing Geo-database and Application

Adjustment module in the application Openmaint done because not all modules are provided will be used on the system infrastructure Jatinangor ITB campus. This application is built using free software use, such as PHP programming language, processing of database PostgreSQL / PostGIS, application processing spatial data GeoServer and BIMServer and package web applications-client Heron that package multiple applications such as OpenLayers, GeoExt and ExtJS into one, as well as BIM Surfer, This software is run or operated on a computer network or the Internet. To be able to use this software, at least in the computer must be connected to the internet and installed web-browser such as Firefox or Internet Explorer Mozzilla.

5. CONCLUSION

The initial results from this study have shown the capabilities for semantic modelling and analysis from the proposed workflow from laser scan, BIM to CityGML. The workflow provides tools and methods for 3D modelling, documentation, management and analysis.

The use of laser scanning and photogrammetry can record very high and accurate levels of detail in the field for building documentation. 3D GIS + BIM provide designers and planners with a useful tool for modeling and analysis. This application enables users to visualize complicated site planning information in the 3D way, to evaluate the allowable capacity of the block and to simulate building plans. With visualization and analysis capability, 3D GIS is considered a powerful tool to solve various issues which modern campus confront.

Finally the integration to CityGML can provide further capabilities for linking the 3D buildings model to information systems. The CityGML model can be integrated into GIS platforms for efficient management and analysis that is required for maintaining important sites.

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