Modelling Immovable Asset in 3D using CityGML 3.0 Concept to Support Smart City Initiatives

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ABSTRACT:

Urbanization phenomenon is a key role that contributes to the smart cities development. The expansion of urban growth requires everything to be smart and controlled by advance technology for efficient urban management. One of the important aspects that often overlooked in realizing smart cities is asset management. Asset management is an approach for managing, monitoring and maintenance of assets. Previous studies showed that there are several efforts in managing asset by integrating the asset with Geographic Information System (GIS). However, several limitations can be seen from the studies such as unavailability of real visualization and limitation on asset descriptions although we believe that 3D offers rich information and real visualization for asset management practice. Therefore, to achieve an effective asset management, we proposed to conceptualize the asset with the latest version of CityGML 3.0. The aim of this paper is to model the immovable asset using CityGML 3.0 concept. We adopted the concept of occupied and unoccupied spaces to model the public hall, owned by Johor Bahru City Council (MBJB). The hall was modelled based on point cloud data set from Terrestrial Laser Scanning (TLS) and Unmanned Aerial Vehicle (UAV). The attribute data for the hall was stored in 3DCityDB for information retrieval and query. The result showed that the hall was successfully visualized and information regarding the asset can be retrieved. With this approach, it is believed that an effective 3D asset management system can be developed in the future, to ensure adequate system performance and effective cost operational.

1. INTRODUCTION

Recently, smart cities have received a lot of attention in various fields. According to Bismart (2020), the main concept of smart city is to employ advance technology in delivering services and solving problems in the city. The basic purpose of a smart city is to use smart technologies and data analysis to optimise city functions and boost economic growth while also increasing people' quality of life (TWI, 2021). The last few years shows that administrators, architects and urban planners have faced significant problems and issues due to rising population in metropolitan areas (Eremia, Toma, & Sanduleac, 2017). Smart city is seeming to be one of the solutions to provide efficient services and management for the population in the city thanks to the incredibly inventive Internet of Things (IoT) solutions. A smart city employs information and communication technology (ICT) to boost operational efficiency, to share data with the public, and to improve government service and citizen welfare (TWI, 2021). With the combination of IoT in a smart city, transportation and accessibility can be improved. Besides that, social services can be enhanced and at the same time, sustainable living can be achieved (Bismart, 2020).

In the last decade, the use of GIS application in the asset management practices practically increased. Many public work organizations have made a large investment into gaining and deploying Geographic Information System (GIS) for geospatial information to track their spatial assets, to maintain historical records and to sustain an accurate inventory (AssetWorks, 2021). Moreover, GIS helps in providing valuable spatial information regarding asset management to these organizations. However, in some sense, traditional GIS could not provide the real visualization of the asset since most of the system is developed in 2D.

The 3D city models are increasingly being used as the tool for different applications related with urban management and planning (Prieto & Izkara, 2011). Meanwhile, 3D visualization is a method to present or to show any result or model or anything related in 3D representation (see Yusoff et al., 2011); (Ujang et al., 2015); (Azri, Ujang, & Rahman, 2018); (Ridzuan et al., 2020). However, the visualization of 3D city model is critically challenge with complex 3D geospatial data due to current smart city demand. So, in this paper, a new approach is introduced. A CityGML concept is being used as data model and visualization of geometry in CityGML. Moreover, more cities and countries worldwide are creating semantic 3D city models of their physical environment based on the international CityGML standard issued by the Open Geospatial Consortium (OCG) over the last decade (Yao et al., 2018).

Due to the recent development of data acquisition (i.e., aerial photogrammetry or sensors), 3D concept started to get attention from various applications especially the 3D city model. A 3D city model is considered as the digital representation of a city that may decompose into its objects (such as buildings, roads, railways, terrain, water, vegetation and more) with clearly defined semantics, spatial and thematic properties (Pispidikis & Dimopoulou, 2019). According to Kutzner, Donaubauer, & Kolbe (2018), modelling and integration of geospatial data plays an important role in the geospatial domain. A model driven approach for data integration can be applied using Unified Modelling Language (UML) for defining the models (Kutzner et al., 2018). In 3D asset management, the data model is utilized to facilitate information sharing, and to discover the spatial and semantic information and the thematic features in 3D city models development. The integration of geometry and semantics in a single data model paved the way for better sharing of virtual 3D city models with the inclusion of thematic modules in OCG CityGML (Saran et al., 2018). Thus, in this study we proposed to conceptualize the asset with the latest version of CityGML 3.0.

2. RELATED WORKS

There are several research studies that focus on asset management. The publications related to asset management topic cover a large scope and there are many different subtopics included.

Some research focus on asset management concept. Woodhouse (2012) specifically explained the concepts and the practices of asset management. Asset management is about professional maintenance, equipment tagging and tracking, and also asset information and work management. Asset management is developed as an approach by public infrastructure sector to achieve more value with fewer resources (Ismail et al., 2019). In Malaysia for example, the quality of asset management began entering new era that is based on holistic approach and sustainability (Noor et al., 2011).

According to Bahri et al. (2019), efficient asset management can be achieved with the integration of Geographic Information System (GIS) due to the advancement of GIS in handling spatial and attribute data. With the current challenges such as big data, a proper data management requires striving cost and operational efficiency (Breunig et al., 2020).

3. IMMOVABLE ASSET MANAGEMENT

Immovable asset management is an immovable property such as land, building and infrastructure which is valuable resources that directly influence the revenue and the expenditure of local authorities (Berahim, Jaafar, & Zainudin, 2015). Immovable assets also known as assets that permanent or natural permanent, cannot be moved, or difficult to remove. According to Samsudin et al. (2020), effective immovable asset management should be among the top priority in providing adequate works space or public space for authority to ensure the services can be delivered and functioned properly and efficiently. Example of immovable assets are buildings, infrastructure and lands. These assets require collection, analysis and management of data for each building and premise components (Samsudin et al., 2020).

In Malaysia, the Immovable Asset Management Procedures (TPATA) provided by the federal government is to guide all government agencies in managing various assets and properties owned by government (0.0 et al., 2020). It is in line with the creation of Malaysian Immovable Asset Management System (MySPATA). MySPATA is a system created by Malaysia Administrative Modernisation and Management Planning Unit (MAMPU) in 2009. The role of MySPATA is for immovable asset registration, management and monitoring. Other than TPATA and MySPATA, Government Asset Management Policy (DPAK) and Comprehensive Government Asset Management Manual (MPAM) are also used as guidelines for immovable asset management in Malaysia.

4. 3D MODELLING

The 3D city models are increasingly being used as the tools for different applications related with urban management and planning (Prieto & Izkara, 2011). 3D visualization is a method to present or to show any result or model or anything related in 3D representation (Yusoff et al., 2011; Ujang et al., 2015; Azri et al., 2018; Ridzuan et al., 2020). However, the visualization of 3D city model is critically challenged with large size and complex 3D geospatial data. So, in this paper, a new approach is introduced. A CityGML concept is being used as data model and visualization of geometry in CityGML. Moreover, more cities and countries worldwide are creating semantic 3D city models of their physical environment based on the international CityGML standard issued by the Open Geospatial Consortium (OCG), over the last decade (Yao et al., 2018).

A 3D city model constructed according to CityGML is shown in this paper. A 3D modelling constructed based on AutoCAD Layer State (LAS file) dataset using SketchUp software. This 3D modelling proposed is to show the asset management of a city model using CityGML concept. The model was constructed based on Level of Detail 3 (LoD3). The study area is Dewan Muafakat Taman Kobena at Johor Bahru, Johor, Malaysia that is also known as Public Hall, owned by Majlis Perbandaran Johor Bahru (Johor Bahru City Council, MBJB). Figure 1 shows the image of Dewan Kobena.

Figure 1. Image of Dewan Muafakat Taman Kobena, Johor Bahru, Johor, Malaysia

The 3D model was constructed using LAS file point cloud data for 3D modelling in SketchUp software supported by two plugins software Undet for Sketchup and Undet Indexer. The LAS file dataset was obtained from two methods which were Terrestrial Laser Scanning (TLS) and Unmanned Aerial Vehicle (UAV). For the TLS method, before the model was developed, point cloud processing called registration was performed. Then, the scanned data from TLS was imported into Topcon Scan Master Software. The point cloud was generated until a complete scan world model completed. The point cloud registration steps included 1) Data Management, 2) Data Registration, 3) Georeferencing, 4) Data Filtering and Cleaning, 5) Data Visualisation and Checking Assessment and finally, 6) Data Exporting (to LAS format). Besides, for UAV method, the process undergoing Photogrammetric Structure from Motion (SfM) image processing using Pix4D software. There were three (3) steps used in Pix4D software which were Initial Processing, Point Cloud and Mesh before finally exported to LAS format. After all the dataset was converted to LAS format, the data was then imported to SketchUp software for 3D modelling.

3D modelling is an important part of 3D visualisation. Moreover, the 3D modelling helps in visualisation requirement that allows more accurate representation of objects especially in 3D city models as well as asset management. To implement the 3D visualisation from the study, the integration between 3D model and CityGML concept is a must. So, a data model can be implemented from this 3D modelling and visualization.

5. MODELLING 3D ASSET MANAGEMENT USING CITYGML 3.0

In CityGML 3.0, a new space concept, a revised Level of Detail (LoD) concept, the representation of time-dependent properties, the possibility to manage multiple versions of cities, the representation of city objects by point clouds, an improved modelling constructions, the representation of building units and storeys, an improved representation of traffic infrastructure as well as a clear separation of conceptual model and data encodings that allow for providing further encoding specification besides GML (Kutzner, Chaturvedi, & Kolbe, 2020). The overview of improved version of CityGML 3.0 is shown in Figure 3.

5.1 Building Module

A revised Building Module is introduced in CityGML 3.0. The building module introduces a new class *AbstractBuildingSubdivision*, in which modelled as a subclass of *AbstractLogicalSpace*, and two specialisation Building Unit and Storey to allow representing building units and storeys (Kutzner et al., 2020). This improved version of CityGML is compatible with 3D asset management application because the immovable assets also apply the same concept as CityGML such as the geometry, the topology, the semantic and the appearance of the building. The thematic surface for building such as *RoofSurface*, *GroundSurface*, *WallSurface* can also be applied to the immoveable asset. The building module introduced in CityGML 3.0 concept are *AbstractBuildin* and *AbstractConstruction* classes. A feature named *AbstractSpac*e is introduced to facilitate 3D asset management into CityGML. This feature allows for mapping constructive element from 3D model datasets onto CityGML. Thus, the component of immovable assets is bounded by thematic surfaces and establishes explicit connection between the constructive elements and their thematic boundary surfaces.

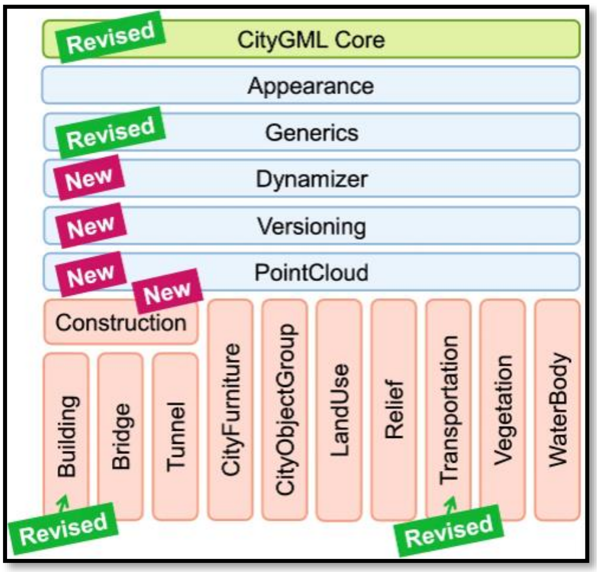

Figure 2. CityGML 3.0 module Overview (Kutzner et al., 2020)

5.2 Space Concept

Other than improved version of building module, Space Concept is a new concept introduced in CityGML 3.0. This concept can be applied for 3D asset management. Based on CityGML concept, the immovable assets are known as physical spaces as they are fully or partially bounded to physical object. For instance, buildings and rooms are physical spaces because they are bounded by walls and slabs. The physical spaces can be classified as occupied spaces and unoccupied spaces. Occupied space is a space that blocked by volumetric object. Both immoveable asset and moveable asset can be categorized as occupied space. For example, moveable assets such as cupboard, chairs, or tables are occupied space representations. Building also can be classified as occupied space representation even though it is categorized as immovable asset in asset management. Meanwhile unoccupied space is something that does not occupy space (i.e., building rooms or traffic spaces). Thus, initial study on functionality needed to be done before categorizing the immoveable and moveable assets into new CityGML space concept.

On the other hand, this paper conducted a study on Dewan Muafakat Taman Kobena, Johor Bahru, Johor, Malaysia. The building is composed of single-story building with building components such as *RoofSurface*, *WallSurface*, *GroundSurface*, *BuildingInstallation*, *Window* and *Door*. In this work, Figure 3 shows the exterior model of Dewan Kobena, a building representing the occupied Space Concept in CityGML 3.0. This building is classified as occupied space as it composed of walls, slabs, rooftop and volumetric objects that occupied the building spaces.

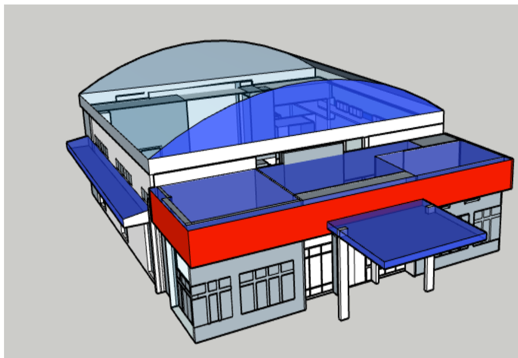

Figure 3. The representation of occupied space from exterior model

In contrast, the indoor space differs from outdoor space in many aspects (OGC, 2019). Therefore, CityGML 3.0 introduces Space Concept to meet the requirement of indoor spatial applications. The indoor spatial information can be catogerized into two categories which are the management of building component and indoor facilities, and the usage of indoor spatial. The first category is related with asset management for indoor spaces. In CityGML 3.0, Space Boundary play important roles in identifying the spaces to be classified as occupied or unoccupied. Besides, it is required to define indoor spaces and constrains (i.e., walls and doors) representated by various spatial elements for asset mangement purposes. Moreover, the immovable assets are permanently or partially attached to the surface on a room or any spaces in building. Hence, the classification of the Space Concept can strongly be used for asset management as well as indoorGML and indoor navigation.

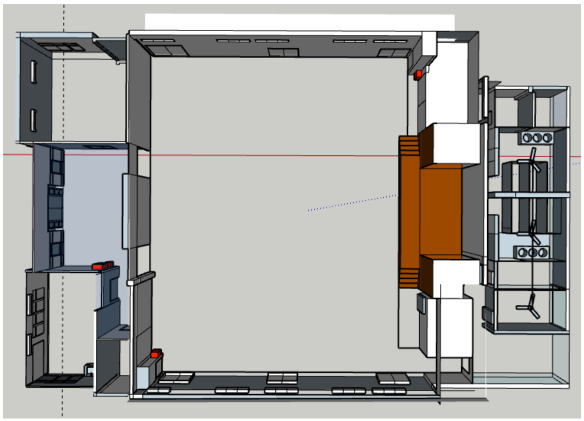

Figure 4. The indoor model of building.

Figure 4 shows the indoor model of building that represents the indoor Space Concept. The indoor model of Dewan Kobena showed different types of building elements and spaces in one building. In Dewan kobena indoor spaces, there were space that representing rooms, halls, lobby and building furnitures. Besides that, the Space Concept of a building can be categorized as occupied space and unoccupied space. According to CityGML 3.0 Space Module, the indoor model of building can futher classify the intertior spatial element between occupied space and unoccupied space based on the boundary of object and volumetric object that occupy the space. Futhermore, take building rooms as example. The rooms in CityGML 3.0 is classified as unoccupied space in contract that building is an occupied spaces. This happen because a room is an empty space and not volumetric object as room is free of matter. The example of building room can be seen in Figure 5. The figure shows the two type of rooms in Dewan Kobena which on the left side is an empty room while on the right side is an occupied room as it has a building furniture in there. However, although both rooms have different perspectives, both rooms are still classified as unoccupied space.

Figure 5. The representation of unoccupied spaces.

By introducing CityGML 3.0, it will be easier to link CityGML with indoor components especially immovable assets. The Space Concept in CityGML helps to clearly identify with spaces or rooms containing immovable assets. Therefore, identifying and classifying the immovable asset will be simpler and faster. Thus, as the basic for asset management, the indoor 3D model should be able to provide various indoor and immovable assets information plus the spatial topological relationship information. The simplified and new CityGML module gives a few advantages especially for building indoor navigation and study.

6. RESULTS

3D visualisation is a representation method for any information, results and models. In addition, a data visualisation is conducted to visualise the semantic and the geometry portrayed by Dewan Muafakat Taman Kobena 3D model. The research focusing on the 3D modelling related to the CityGML application. Moreover, for CityGML 3D model visualisation, 3DCityDB application being used. 3DCityDB is an open-source platform to facilitate the development and the deployment of 3D city model applications. Besides, 3DCityDB software is a tool that allow importing, storing, managing, analysing, visualising and exporting virtual 3D city models according to the CityGML standard (Yao et al., 2018). Figure 6 shows the components related to 3DCityDB software. All components in 3DCityDB were being used to visualise a CityGML 3D model. The process of visualisation for 3D CityGML model is conducted by importing and exporting data, before the visualisation.

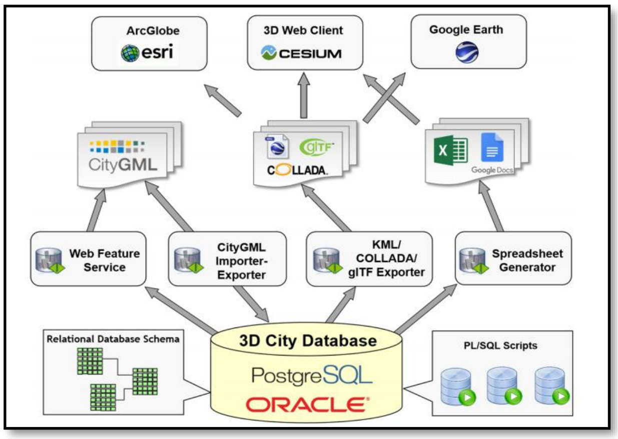

Figure 6. The components of 3DcityDB software (Yao et al., 2018)

In this paper, the visualisation process of CityGML 3D Model began with the 3D modelling of Dewan Muafakat Taman Kobena. Figure 7 shows the result of 3D CityGML model of Dewan Muafakat Taman Kobena. The CityGML model is portrayed in the CityGML 3.0 representation. Thus, this CityGML 3.0 3D model is the format set for 3D city models in particularly to import the CityGML datasets into 3DCityDB.

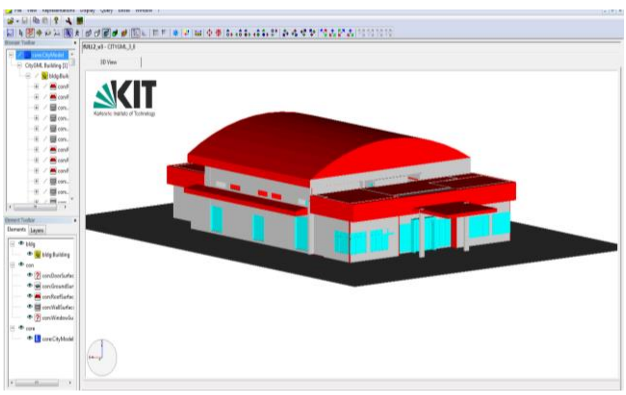

Figure 7. Dewan Muafakat Taman Kobena CityGML 3.0 representation model.

After that, a database was created for 3DCityDB using PostgreSQL tool. PosgreSQL was being used as a tool to store geospatial data that link to the 3DCityDB. Then, the CityGML

3D model of Dewan Muafakat was imported into 3DCityDB to load the 3D model content. Besides, the importer supported regular XML files, GZIP compressed XML files, and ZIP achieves. Other than that, in PosgreSQL, the database can be edited based on the user specification to insert, to update, to delete and to rename the data. Figure 8 shows some simple queries on building information of Dewan Muafakat Taman Kobena. The information contained building id, building address, building function, coordinates and 3D model date of creation. This function could help the users to easily find the information regarding the building. Then, in 3DCityDB, the CityGML 3D model would be exported between XML export or KML/COLLADA/gITF based on the requirement. Finally, a visualisation was created for a 3D model of Dewan Muafakat. The visualisation method was based on the scope and result required by the study either general visualisation or web-based visualisation.

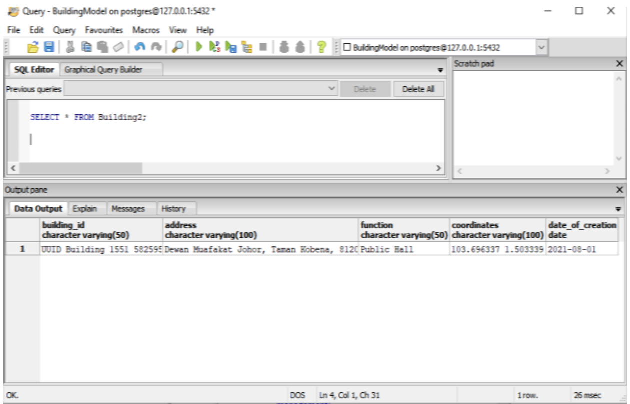

Figure 8. Simple query for CityGML 3D model

7. CONCLUSION

As conclusion, GIS application plays important role to aid in smart city development. Smart city is an important application that helps in administrating, monitoring and improving the government and citizen welfare. Therefore, 3D asset management is one of the GIS applications that helps in smart city development. The integration of smart city concept and GIS can help in managing, monitoring and analyzing all asset activities and associated works. Besides, the modern GIS technology enables to produce a modern, user-friendly, and open-source information system that can help in managing assets. Moreover, GIS is used throughout the life cycle of smart city from the site selection and design through visualization and construction to maintenance. The asset management is an application that integrate with current technology to alleviate energy consumption. In addition, asset management is one of the applications of smart city in improving city management including monitoring and maintenance of building immovable assets.

3D asset management is not a new approach that has been introduced for a few years. Nowadays, the demand for 3D asset management for smart city towards sustainable management is increasing. In Malaysia, the government also has introduced the system for managing and monitoring immovable asset for government agencies. Unfortunately, the system is not being utilized by all government agencies due to data complexation and documentation. Thus, in this new decade of modernization, there is a need for system management that includes spatial data management and 3D visualize module. In this part, CityGML concept plays an important role for 3D city model. CityGML concept contains various features and module for data integration, data management and 3D visualization. Besides, CityGML is the most suitable data model for smart city as it complies with the International Standard. CityGML standard also can be used for other applications such as urban and landscape planning, 3D cadastre, architectural design and more.

This paper focuses on CityGML 3.0 concept in handling asset management. From the result, a 3D CityGML model has been successfully constructed through SketchUp software based on the building floor plan and data acquisition. Briefly, the new Space Concept and improvised building module has possibility in representing and managing 3D asset management. This modelling concept can assist asset managers and building owners regarding asset information and management. Hence, with this paper, one can get better understanding on modelling the asset in 3D using CityGML 3.0 concept.

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