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Web Visualization of 3D Strata Objects Based on CityJSON and LADM

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Key words: 3D strata objects, 3D modelling, CityJSON, database, web visualization.

SUMMARY

Owing to population growth in Malaysia, there have been significant stratified subsurface and aboveground developments, particularly in densely populated areas, posing a challenge to the current land administration system and the urge to constantly improve. Land Administration Domain Model (LADM) provides a relatively generic spatial representation model for a variety of spatial units, such as 2D land parcels and 3D legal spaces around structures and utilities. As a result of standardization, the LADM data model becomes more flexible, making spatial data management easier. On top of that, 2D-based cadastral systems experience challenges when it comes to documenting, handling, and visualizing the spatial extent of vertically stratified cadastral spaces. 3D strata object visualization is typically represented using third-party software that requires professionals and limits the number of users of cadastre data. The necessity for a 3D visualization platform has been realized by many researchers. A number of 3D Cadastral prototypes have been developed in several countries, including Australia, Russia, and Indonesia. Moreover, 3D visualization improves user communication, decision-making, and the management and facilitation of land information systems. This paper attempts to expand the depiction of those strata objects in 3D by implementing CityJSON based encoding. The focus is mainly on the visualization of the 3D strata parcels above ground, and CityJSON data format for 3D spatial data modelling, and to link the 3D Strata Viewer with the database (legal information) of the 3D parcel using a web-based platform based on LADM Country Profile. This paper describes the implementation of the conceptual model of strata objects based on the Malaysian LADM Country Profile for the representation of spatial and non-spatial strata data. Tools such as FME as data manipulation and conversion and Ninja to handle and visualize 3D strata objects in a browser. The work demonstrates the development of Strata Application Domain Extension (ADE) of CityJSON within LADM. The viewer is able to display all the inquiries about strata such as ownerships, administrative and spatial source, rights, restrictions, and responsibilities (RRR). The developed ADE offers different insights for the strata objects management especially in the case of the Malaysian scenario**.**

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1. INTRODUCTION

Rapid expansion and burgeoning construction of housing and developed infrastructures limit the number of land lots available, forcing developers to create multi-level and vertical buildings. The practice of documenting and sharing information on everything linked to land and its associated resources was referred to as land administration (Mattsson & Mansberger, 2017). Moreover, the availability of a reliable information system is critical for the successful management and ownership of property objects and spaces above ground, as well as their related operation and ownership rights (Budisusanto et al., 2013). This type of information system should be able to handle information related to 2D and 3D geometries, as well as their associated attributes, that represent the intricacies of rights, restrictions, and responsibilities of 3D objects. Land Administration Domain Model (LADM) standard provides a formal conceptual model for recording and managing cadastral data (Rajabifard et al., 2019). Malaysia has also adopted the data model for the purpose of representing strata objects which includes building and building parts (all in 3D within a single lot), land parcel (with houses not more than 4 stories within a single lot), parcel unit, accessory unit, common property unit, and limited common property unit (Jamil et al., 2017; Zulkifli et al., 2021).

A strata property is defined as a scheme where the building or land is carved out into different lots of parcels that includes high rises such as flats, apartment, condominium, and townhouses (Bhatt, 2020). 2D sketches are widely used to construct property documents such as floor plans, cross-sections, and isometric diagrams. Despite the fact that these plans are common procedures for practitioners', laymen find it difficult to grasp and perceive this type of drawing (Shojaei et al., 2012). People move, think and experience in 3-dimensional life which in many cases, representation of data in 3D visualization helps provide solutions as it depicted realistic image that allows easier interpretation and improves decision making. 3D applications have traditionally relied on high-end computers and commercial software such as ArcGIS Pro, Revit, SketchUp Pro, etc. The usage of a desktop program has proven to be a useful tool for recording, storing, analyzing, and disseminating land data. Today, the internet, which serves as an online platform, aids in enhancing interoperability when it comes to sharing and accessing 3D Cadastre data and issues. Displaying spatial data in a web browser allows for easier data sharing across various types of users.

This paper describes the implementation of the conceptual model of strata objects based on the Malaysian LADM Country Profile for the representation of spatial and non-spatial strata data. Tools such as Feature Manipulation Engine (FME) as data manipulation and conversion and Ninja to handle and visualize 3D strata objects in a browser. The work demonstrates the development of Strata Application Domain Extension (ADE) of CityJSON within LADM. The viewer is able to display all the inquiries about strata such as ownerships, administrative and spatial source, rights, restrictions, and responsibilities (RRR). The developed ADE offers different insights for the strata objects management especially in the case of the Malaysian scenario.

This paper is organized as follows: Section 2 describes the background of the study that includes the concept of land administration and strata application along with the existing Malaysian LADM Country Profile and CityJSON. The requirement of strata is stated in Section 3. The implementation part where the experiment takes place including the architecture design, data conversion, conceptual model, and visualization were discussed in Section 4. Finally, a conclusion is in Section 5.

2. BACKGROUND

This section discusses the concept of land administration, strata application, Malaysian LADM Country Profile, and CityJSON.

2.1 Land Administration

The process of documenting and conveying information on the possession, value, and use of land and its associated resources, including the determination of rights, land attributes, survey, and extensive documentation used to support the land market, is referred to as land administration (UNECE, 1996). There are two authorities in Malaysia responsible for handling the administration of land that is Department of Survey and Mapping (DSMM) and Land Offices. Both of these government authorities play a crucial role in handling and coordinating spatial and non-spatial components of land administration data (Zulkifli et al., 2019). However, both of these main organizations held data differently. According to Halim et al., (2021), for strata title preparations, Land Offices manages strata ownership and registration with *eTanah* (eLand). At the same time, DSMM uses eKadaster to handle the spatial component and Strata Title Plan preparation. Both systems are still 2D in nature.

2.2 Strata Application

There have been significant stratified subsurface and aboveground developments in urban areas due to population growth in Malaysia (Rajabifard et al., 2021). High rises building such as flats, apartments, condominiums, townhouses, shop houses are all categorized under strata property. The terms that are commonly used in strata management include parcel unit, accessory unit, and common property unit. A parcel unit is an individual cubic entity formed by the walls, ceilings, and floor, comprised in a sub-divided building held under separate strata title. Besides that, there is also common property which is the partition of a building that is not part of the individual parcel issued by the management corporation. An accessory unit is any parcel identified in a Certified Plan (CP) that is utilized in conjunction with a parcel that is used only by the owner or buyer of the parcel unit.

2.3 Malaysian LADM Country Profile (Strata Objects)

The LADM is a conceptual model and one of the first spatial domain standards within ISO TC211, with the goal of providing an extensible foundation for efficient and effective Land Administration System development based on a Model-Driven Architecture (MDA) and allowing involved parties to communicate based on the shared ontology implied by the model (Kalogianni et al., 2020). This standard is related to four packages which are parties (people and organizations), basic administrative units, rights, responsibilities, and restrictions (ownership rights), then, a spatial unit (parcels, and the legal space of buildings and utility networks), also spatial sources (surveying) and spatial representations (geometry and topology) (ISO, 2012).

Multiple country profiles have been developed including Malaysia, as well as several LADM implementations through technical models and encodings. Furthermore, with the growing demand for 3D land administration data, LADM has been widely used around the world since it allows the 3D representations of spatial unit representations without burdening the existing 2D representations (Kalogianni et al., 2020).

In Malaysia, Zulkifli et al., 2014 have proposed a country profile (data model) for 2D and 3D cadastral registration based on LADM specifications using 'MY' as a prefix for Malaysian Country Profile. It consists of two parts: spatial and administrative. In the case of strata objects representation, it has parcel, accessory parcel, common property, limited common property, and land parcel (Zulkifli et al., 2019). The Strata Titles Act 1985 (Act 318) and the Strata Management Act 2013 (Act 757) are crucial for most of the land administration in Malaysia, and this is particularly true in many 3D-related situations. According to Zulkifli et al., (2021), the development of the conceptual model of strata objects is based on the LADM standard, strata XML scheme, and User Requirement Analysis (URA). The involved authorities - DSMM and Land Offices have both accessed and verified the generated model as it met their requirements in terms of comprehensiveness and the ability to accommodate a wide range of the spatial unit, including strata objects (Zulkifli et al., 2021).

2.4 CityJSON

CityJSON is a JSON-based exchange format for the CityGML data model. It is an open data model and exchange format to store digital 3D models of physical objects and is standardised by the Open Geospatial Consortium (OGC). It defines different levels of detail (LoDs) for the 3D objects, allowing us to represent 3D city objects for different applications and purposes (Ledoux et al. 2019).

The aim of the CityJSON data format is to provide support for almost all the features of CityGML, while at the same time maintaining a simple file structure that allows developers to easily manipulate CityJSON files. One of the main reasons for CityGML's poor interoperability is the complex and verbose nature of its main encoding, which is based on GML. (Vitalis et al. 2020). CityJSON is more compact than CityGML and these techniques decrease the file sizes of datasets even further, allowing for faster transmission over a network (van Liempt, 2020). The encoding allows us to create a lightweight dataset for the exchange and visualization of 3D strata models.

Moreover, CityJSON also supports extensions to the core data model of CityGML for specific applications and use-cases; these are called ADEs (application domain extensions). The extensions are defined as simple JSON files and support the addition of new feature types, as well as the addition of new attributes for features and for datasets. There are several extensions that have been developed for the CityJSON based on specific applications and use cases such as LAS point cloud, noise, generic city objects, topological information, and city model data quality. Therefore, this paper demonstrates the 3D Strata ADE of CityJSON within Malaysian LADM.

3. STRATA REQUIREMENTS

Cadastral parcels are 2D to 3D groupings of spaces situated all over the world, with various levels of complexity established for parcel representations. Kalogianni et al. (2020) classify several 3D objects that correspond to subsurface or above-ground features, as well as the land/water surface. The requirements for 3D strata objects, which are also considered 3D objects, are essentially the same as for other cadastral objects. The following is a list of it:

a) Examine the strata property units in the context of the surrounding 3D environment.

b) To locate a specific 3D strata property unit.

c) To distinguish the boundaries of 3D strata property units and the associated building parts

d) To identify and understand the 3D legal boundary of the strata property units

e) Find adjacent objects of a 3D legal object, both vertically and horizontally to identify affected Right, Restriction, and Responsibility (RRR).

f) To distinguish the private and common property in a strata development.

g) Identify units that are to be merged or subdivided.

h) Visually check the spatial validity and data quality, e.g., volume is closed, no overlap between neighbouring volumes, and no unwanted 3D gaps.

i) Perform 3D measurements such as calculating the surface area or volume of the strata property.

j) Support other management systems such as land taxation, urban planning, registration, and many more.

4. IMPLEMENTATIONS

The conceptual model for strata objects is based on the Malaysian LADM Country Profile. The work attempts to implement an Application Domain Extension (ADE) based on CityJSON called Strata ADE. The data in the workflow shown in Section 4.1 consist of 3D modelling, and also conversion prior to the web platform visualization (Ninja).

4.1 Architecture Design

The architecture is divided into two tiers, as shown in Figure 1: data tier, and client application tier. The 3D models and administrative data are included in the data tier. The 3D model derived from skp. was exported to KMZ file which was then transformed into CityJSON in order to be able to view on Ninja viewer. Based on the existing data, it was then classified into LADM classes by implementing Malaysian Country Profile (Strata) based Unified Modelling Language (UML) using Enterprise Architect. Then, the data were transferred to PostgreSQL by establishing the connection using ODBC Data Sources with Enterprise Architect.

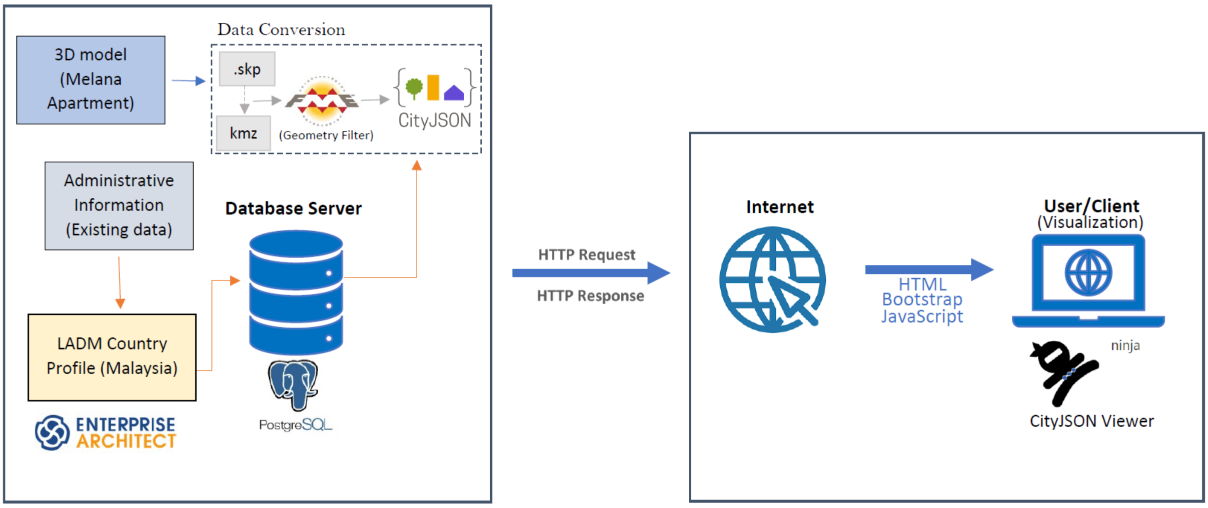

Figure 1. The workflow of the architecture design

4.2 Conceptual data model (Strata Objects)

In this stage, LADM based classes that need to be included in the data model has been recognized, along with their attributes and relationship. The models are divided into two categories: spatial and non-spatial components, as discussed in Sections 4.2.1 and 4.2.2. The prefix 'MY' refers to the Malaysian country profile, that covers both spatial and administrative data modelling.

4.2.1 Spatial components

In the model, one strata object type remains to be represented in 2D, MY_LandParcel (with building no more than 4 stories). The other strata objects are all proposed to be in 3D as shown in Figure 2 (blue classes) and therefore inherit from an abstract class (MY_Shared3DInfo) with strata specializations (and mutual aggregation relationship) called as MY_BuildingUnit, MY_ParcelUnit, MY_AccessoryUnit, MY_CommonPropertyUnit, and MY_LimitedCommonPropertyUnit.

Malaysian country profile has indicated several abstract classes that are: MY_SpatialUnit, MY_Shared3DInfo, MY_GenericLot. These classes are used only to support the modelling process, to represent shared attributes, and will not get any instances (and therefore no corresponding table in database implementation).

4.2.2 Non-spatial components

The non-spatial component consists of object classes that are used to represent the legal aspect of LADM. It consists of the Party (green classes) and Administrative packages (yellow classes) as shown in Figure 3. In party packages, the main class is called as MY_Party, MY_GroupParty represents any number of parties forming together as an entity and Party member.

The packages are associated with each other to show the relationship of ownership with their rights. The administrative packages are related to an abstract class of MY_RRR with three main subclasses called MY_Right, MY_Restriction, and MY_Responsibility. A subclass of MY_Mortgage is inherited by MY_Restriction associated to MY_Rights such as transfer, lease, charge, easement, caveat, and others. It may be associated with zero or more rights.

A BAUnit represents the basic administrative unit as a subject registration (by law) consisting of zero or more spatial units with a unique (held by one or more parties) and homogeneous rights, restrictions, and responsibilities as included in the land administration system (ISO, 2012). A BAUnit has a unique identifier when registered or recorded but it can consist of zero spatial units, when the registry exists but not a cadastre. Hence, the MY_BAUnit classes are used to register the basic property units, which consist of several spatial units belonging to a party under the same rights.

The most important element in the administrative package is called MY_AdministrativeSource as it holds the document as evidence showing the rightful owner. It is also used to describe and transaction (deed) or a judgment of the registered holder. MY_AdministrativeSource is associated with MY_RRR and MY_BAUnit. In Malaysian LADM country profile, the identifier for the administrative source is the title number. However, there are additional classes added in the administrative part of the data model which is called as MY_Developer class which is crucial for strata management. The developers are responsible for managing and maintaining the buildings as well as controlling legal funds, insurance, and many more.

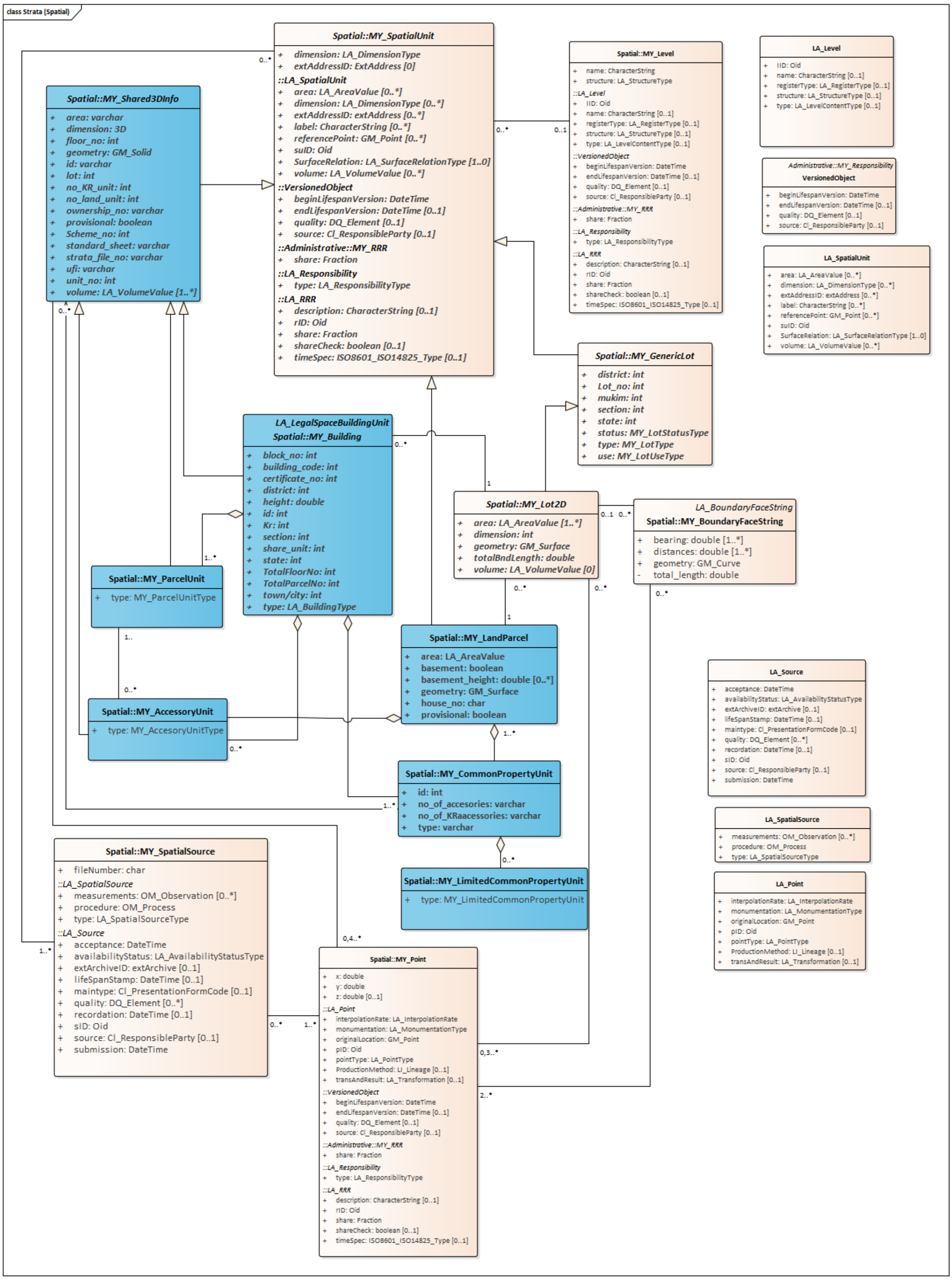

Figure 2. The spatial components of strata objects – Malaysian based Country Profile

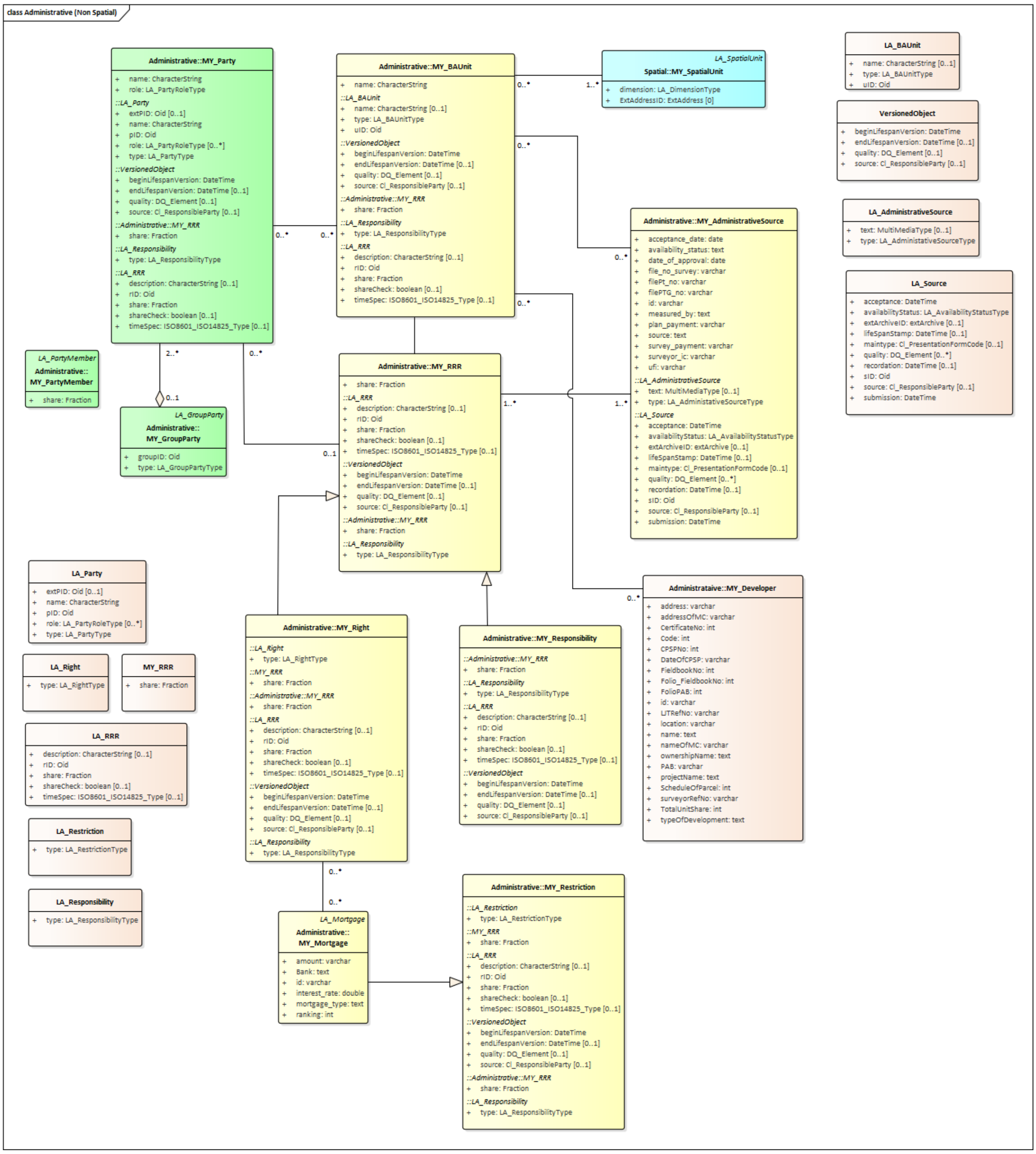

Figure 3. The non-spatial components of strata objects – Malaysian based Country Profile

4.2.3 Strata ADE

The Strata extension is developed to support 3D spatial data modelling, that links with the database (legal information) of the 3D parcel based on LADM Country Profile. Figure 4 below shows the new attributes added to the Building object based on CityJSON classes (light blue represents core classes). The Building object class will have additional attributes (legal information) inherited from the tables MY_AdministrativeSource and MY_Shared3DInfo.

These tables contain legal data related to the administrative (surveyor, party, submission, etc.) and spatial 3D info (area, dimension, floor no, ownership, volume, etc.)

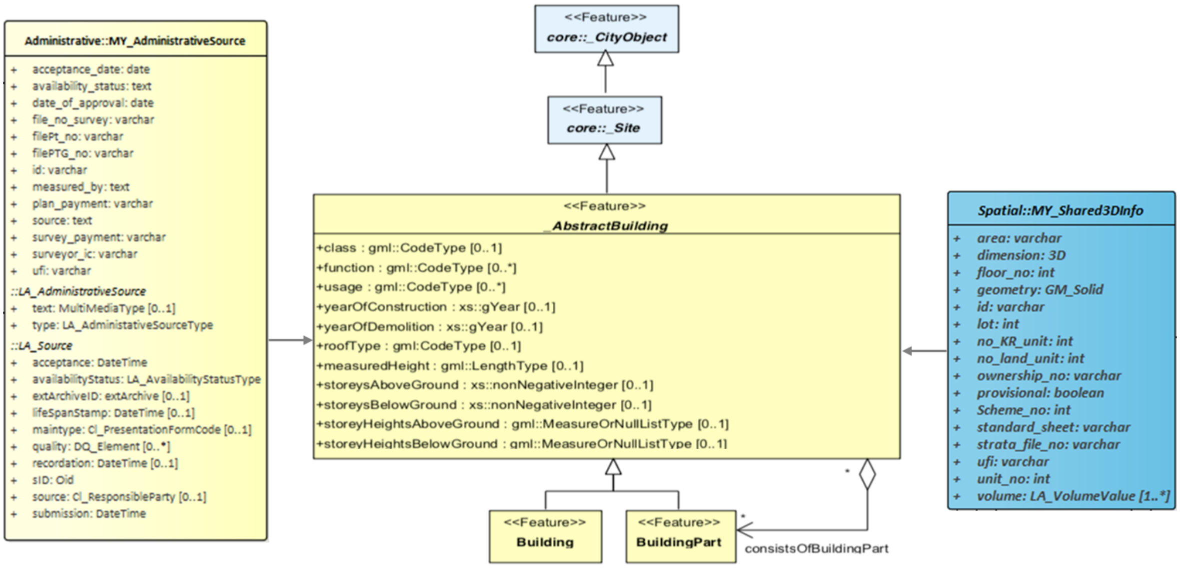

Figure 4. Adding new attributes (MY_AdministrativeSource, MY_Shared3DInfo) to the Building object of CityJSON classes.

4.3 Data Conversion

FME provides built-in support to simply read and write data in order to convert it from one format to another. From SketchUp, the data was exported to KML/KMZ file. Since the model is georeferenced, it carries a geographic coordinate system (WGS 84) and can be viewed via Google Earth. The data can be translated to CityJSON once the model has been successfully viewed on Google Earth. To do this, Format OGC/ Google KML as a reader, and CityJSON as the writer. Placemark is chosen as the selected feature type as it carries geometry details. The KML reader reads the KML dataset that conforms to the KML specifications. KML uses a tag-based structure with nested elements and attributes and is based on the XML standard. Transformers called Geometry Filter were added to the workflow as shown in Figure 5. A geometry filter was used to routes a feature based on its geometry type which in this case is a 'surface'. Each feature that enters the transformer is output via the port corresponding to its type. Each output feature has a complete, unaltered copy of the source feature's attributes and geometry. It's a 1:1 data conversion which means CityJSON can read each unit individually.

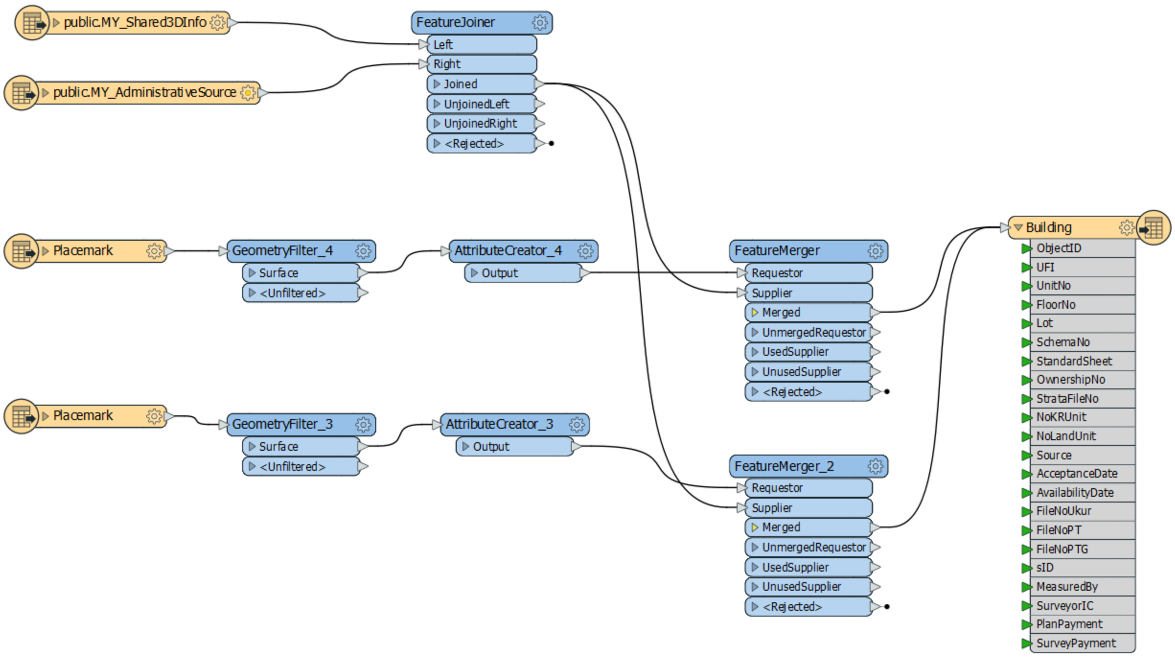

Figure 5. The workflow of the conversion model

In order to add the attributes, or the administrative information that has been stored in the database, a new connection has to be made in FME. Once, the connection is successfully established, the tables are linked using 'feature joiner' transformers. However, since the 3D Strata model has been defined with ObjectID (e.g., U1L2, U1L3), the non-spatial data must be linked with their own identifier, ObjectID. LADM carries attributes in terms of classes, and ObjectID is stored as an identifier in each class. Hence, data filtering is required in order to read only the records in each table established by LADM. It was done using 'Attribute Creator' and 'Feature Merger' transformers. Figure 5 shows the whole process of linking the 3D model, and their administrative information stored in the database.

4.4 Visualization

The visualization is done on Ninja since it is made up of Vue components that offer individual functionality when working with CityJSON data. It is primarily made for viewing in CityJSON file format on the web application (Vitalis et al., 2020). The reason why we chose Ninja as the viewer is that it supports all typical geometric types encountered in real-world datasets which in this case is MultiSurface. Besides that, Ninja also provides a clear way for the user to easily understand the semantics aspects of the city model (i.e., its object type – buildings and geometric types. The capacity of the viewer to display specific information or properties of the objects is the most important consideration as well as the user's ability to access and alter raw CityJSON information. However, strata data is recognized as restricted classified data and requires a security clearance process before obtaining or editing data. First, we experiment with the data of 2 strata units as shown in Figure 6 to show the linking of the spatial and non-spatial components. Figure 7 shows the visualization of the entire block which consists of 64 strata units with 4 floors. The developed ADE able to access, view, and query the legal data on web platform which was limited within CityGML. Also, CityJSON able to store the geometry and attributes of the strata units in a file with prefix .json (for data exchange purposes).

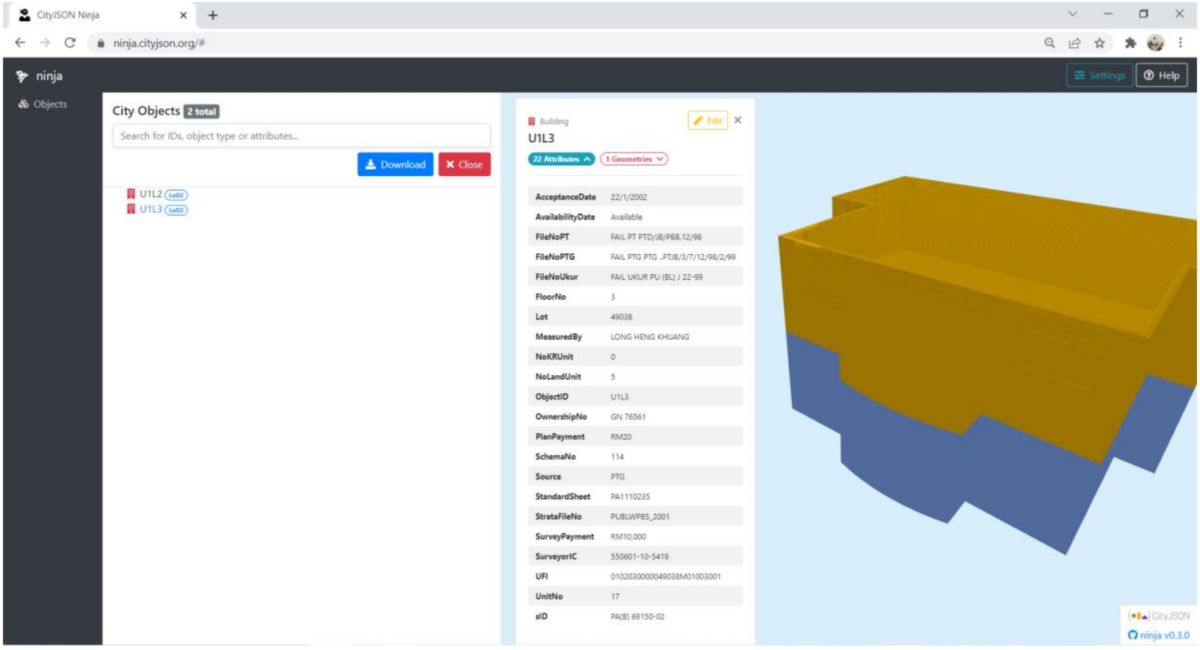

Figure 6. The visualization of strata unit with its administrative information

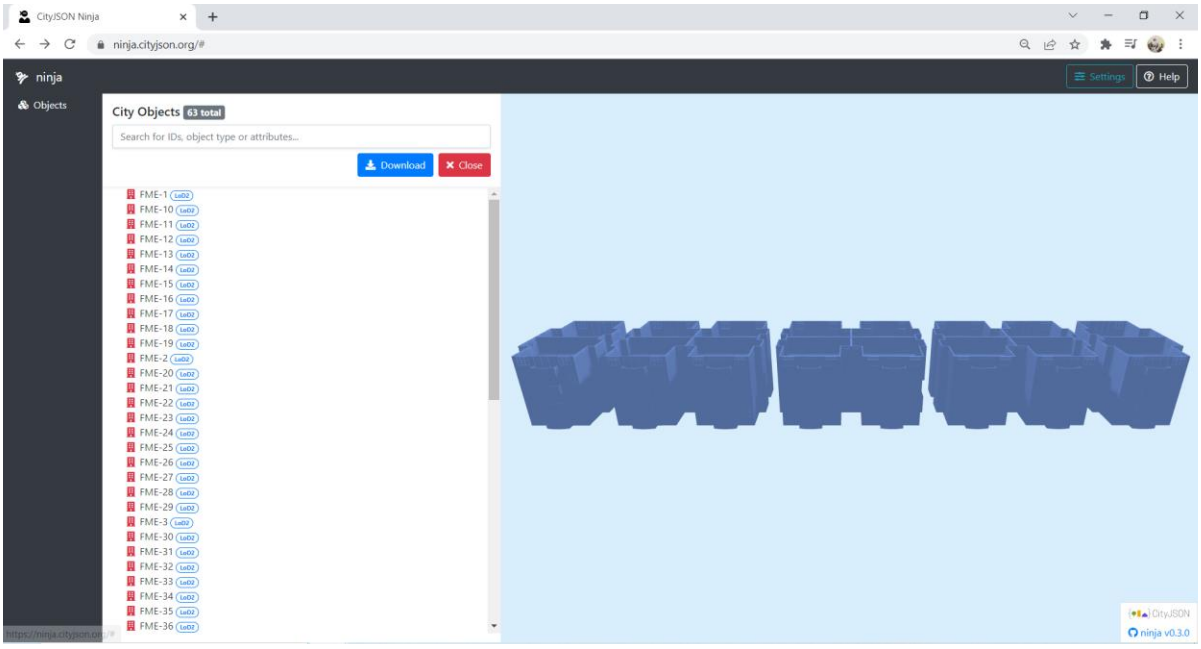

Figure 7. The visualization of the whole building

5. CONCLUSION

This paper demonstrates the workability of the Strata Application Domain Extension (ADE) of CityJSON within LADM. The work implements the conceptual model of strata objects based on the Malaysian LADM Country Profile for the representation of spatial and non-spatial strata data. Data manipulation and conversion were executed by using FME and Ninja for the visualization. As a result, the web app able to display, query, and update the attributes of strata such as ownerships, administrative and spatial sources, rights, restrictions, and responsibilities (RRR). For future work, we intend to address other important features such as stratum and spatium (subsurface cadastre units and objects).

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BIOGRAPHICAL NOTES

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