Database Design and Development of 3D Cadastral Registration based on LADM

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Key words: database design, data modelling, 3D cadastral, strata, LADM

SUMMARY

In this paper, the database design and development of a prototype 3D cadastral registration will be presented. The key aspects of this prototype are the model is based on Land Administration Domain Model (LADM). The LADM provides a conceptual description for land administration system, including a 3D cadastral registration. LADM defines 3D parcel as a spatial unit against which (one or more) unique and homogeneous rights (e.g. ownership right or land use right), responsibilities or restrictions are associated to the whole entity based on ISO 19152. Spatial units have two specializations: legal spaces buildings and legal spaces networks. Here, we only focus on the 3D space of spatial unit based on strata objects representation. Other spatial units are out of the scope. In case of strata objects representation, it has parcel, accessory unit, common property, limited common property and land parcel. The prototype development begins with the data modelling based on LADM (i.e. selecting relevant model classes and extending the model with attributes and classes where needed). The LADM supports various options for representing spatial units; e.g. a 2D parcel or a 3D volume. 2D parcel is recognized, however, how to create and maintain 3D valid parcels is still a challenge in practice. There have been several research and development activities in the past on the LADM. However, these investigations mainly remain at the conceptual level and yet to be implemented in the real context. Therefore, the motivation of this paper is to discuss the practical pathway towards realising an LADM-based 3D cadastral registration in alignment with jurisdictional settings in Malaysia. This paper extends the model in LADM to create a prototype and confirm its feasibility in implementation. It focuses on data migration from existing database (i.e. .xml format) to open source database (i.e. Postgres) based on LADM standard. The visualization and application for the implementation are using open source platform (i.e. QGIS). This research not only important for Malaysia, but also useful for many other countries, that also have the strata title system. Further investigation is on the full potential of LADM for the Malaysia Information Infrastructure (i.e. SDI) development.

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1. INTRODUCTION

Human beings act not only on the earth's surface, but also above and below it. Population growth and intensive land development have resulted in 3D land use and development. Traditionally, individual property units are expressed by 2D planar land parcels using boundaries. However, the rights of 2D land parcels relate to a space in 3D. Furthermore, the true property units exist in 3D environment. An accurate 3D description of cadastre and property become important needs of the land administration system.

There are many cadastral models generally produced by researchers such as Core Cadastral Data Model (Henssen, 1995), FGDC Standard Reference Model (FGDC, 1996), Legal Property Object Model (Kalantari et al, 2008), ePlan Model (ePlan, 2010), Land Administration Domain Model (ISO, 2012) and 3D Cadastral Data Model (Aien, 2013). These data models need to be assessed and compared based on selected criteria. The aim was to analyse how they manage RRRs and meet 3D cadastre's requirements and what data modelling techniques they use to support 3D data.

Standardization makes your data model flexible and that makes working with your data much easier. LADM is an important model to create standardized information services in an international context, where land administration domain semantics have to be shared between regions, or countries, in order to enable necessary translations. The LADM supports various options for representing spatial units; e.g. a 2D parcel or a 3D volume. 2D parcel is recognized, however, how to create and maintain 3D valid parcels is still a challenge in practice. Having a standard is one important step, but the implementation forms the next required step in practice.

The prototype development begins with selecting relevant model classes based on LADM and extending the model with attributes and classes where needed. It focuses on data migration from existing database (i.e. .xml format) to open source database (i.e. Postgres) based on LADM standard. The visualization and application for the implementation are using open source platform (i.e. QGIS).

This paper is organized as follows: Section 2 describes a review of existing cadastral data models (i.e. Core Cadastral Data Model, FGDC Standard Reference Model, Legal Property Object Model, ePlan Model, Land Administration Domain Model and 3D Cadastral Data Model). The conceptual model of strata objects based on LADM (i.e. spatial and administrative parts) are elaborated in Section 3. The conversion of sample data from JUPEM (i.e strata xml) into LADM standard is discussed in Section 4. Section 5, presents the development of the 3D cadastral registration prototype based on open source software (i.e. Postgres and QGIS). Finally, the conclusions are presented in Section 6.

2. REVIEW OF CADASTRAL DATA MODELS

An appropriate cadastral data model plays an important role to ensure a successful development of the cadastral system. A cadastral data model needs to reflect the complexity of cadastral legal objects. In order to choose an appropriate cadastral data model for strata objects in Malaysia, it is required to explore the theories and concepts of existing cadastral data models. Six cadastral data models have been reviewed for this purpose (i.e. Core Cadastral Data Model, FGDC Standard Reference Model, Legal Property Object Model, ePlan Model, Land Administration Domain Model and 3D Cadastral Data Model). These data models were assessed and compared based on selected criteria (i.e. core objects, basic spatial unit, other forms of spatial units, reference documents, applications, inclusion of other types of interest, temporal aspects and semantic level).

Data models are normally developed to achieve specific purposes. Data modellers decide how to model the data to fit the type of problems they are trying to solve. Since land administration requirements differ among the jurisdictions, various cadastral data models have been developed around the world. However, four basic issues are common to them all:

i. They do not facilitate efficient representation and analysis of 3D cadastral object

ii. They are not semantically enriched

iii. They do not integrate physical and legal objects into cadastral data models

iv. They do not based on standards

Most of the cadastral data models such as the Core Cadastral Data Model, FGDC Standard Research Reference and Legal Property Object Model were developed based on 2D land parcels. A few of them, such as ePlan Model, Land Administration Domain Model and 3D Cadastral Data Model, maintain 3D cadastral objects. LADM uses *LA_BoundaryFaceString* class to represent a 2D spatial unit (i.e. land parcels), and *LA_BoundaryFace* class to represent a 3D spatial (i.e. apartment units). These classes are defined by associating to *LA_Point* and *LA_SpatialSource* class.

Current cadastral data models (i.e. Core Cadastral Data Model, FGDC Standard Research Reference, Legal Property Object Model and ePlan Model), objects that represent legal entities are not geometrical semantically enriched. This means that the content of the data is not enriched by categorizing data in relation to each other. Semantic enrichment is reducing the ambiguities for geographic integration and geometrical inconsistencies (Kolbe, 2009). Well-known examples for these inconsistencies are 'flying' or 'drowning' buildings, when a Digital Terrain Model (DTM) and 3D building models from different sources are combined

(Stadler and Kolbe, 2007). The LADM provides geometry semantic by introducing *LA_BoundaryFace* class, which is used to represent *LA_SpatialUnit*.

Since cadastre was developed for legal purposes, current cadastral data models only represent legal objects and do not integrate their physical counterparts. This trend is working well in 2D cadastre where the land parcels represent the corresponding physical land boundaries as well. However, in 3D cadastre, objects are represented by physical structures such as walls, floors, and ceilings in the buildings, are integrated so that the cadastral data model facilitates management and representation of 3D legal objects. Among the cadastral data models, the LADM integrate between legal and physical objects by introducing *LA_BAUnit* class. The *LA_BAUnit* class is an administrative entity, subject to registration or recordation consisting of zero or more spatial units against which (one or more) unique and homogeneous rights, responsibilities or restrictions are associated to the whole entity, as included in a land administration system. The LADM's legal objects are connected using object identifiers to the physical objects.

3. CONCEPTUAL MODEL OF STRATA OBJECTS

The development of the conceptual model of strata objects is based on the LADM standard, strata XML scheme and URA that are obtained from DSMM and Land Office officers. Basically, the conceptual strata model is part of the Malaysian LADM Country Profile (Zulkifli et al. 2014, Zulkifli 2014). The developed model was evaluated and verified by the DSMM and Land Office. These units agreed and were satisfied because the model fits their requirements by being more comprehensive and can support a very wide range of spatial units including strata objects.

Unified Modelling Language (UML) is used to develop the conceptual model. In the conceptual modelling stage, classes that need to be included in the data model are recognized, together with the attributes and relationships of the classes. The conceptual model is important to determine the parts of the real world which are significant for a particular purpose. The model also needs to have a high abstraction level since it is the basis of the conception procedure. It consists of a schematic representation of the real-world and how the objects are connected.

Basically, a conceptual model presents an overview of the whole process at the earlier phase of any spatial data modelling phase, e.g. the development of conceptual model of strata objects. A good conceptual model should be developed in such a way that it is easy to understand.

The development of the strata model is unique because it can support a very wide range of object such as parcel unit, accessory unit, common property unit, limited common property unit and land parcel. The strata objects model also would be useful for Malaysia and countries with similar land administration systems. The conceptual model of strata object is divided by two parts (i.e. spatial and administrative parts).

3.1 Spatial Part

In the conceptual model of strata objects, spatial units can be in 2D or 3D forms. Land parcels are in 2D, but the building is in 3D with volumetric descriptions (without topology). There are several abstract classes in the Malaysian country profile as indicated in Italics: *MY_SpatialUnit, MY_Shared3DInfo, MY_GenericLot*. These classes are only supporting the modelling process, representing shared attributes and structures, and these abstract classes will not get any instances (and therefore no corresponding table in the database implementation).

Topology is not used for strata objects. In the model, one strata object type remains to be represented in 2D, MY_LandParcel (with building no more than 4 storeys). The other strata objects are all proposed to be 3D and therefore inherit form an abstract class MY_Shared3DInfo, with strata specializations (and mutual aggregation relationship): MY_BuildingUnit, MY_ParcelUnit, MY_AccessoryUnit, MY_CommonPropertyUnit, and MY_LimitedCommonPropertyUnit. As there can be several LimitedCommonProperty's in one CommonProperty, this is modeled as a part-of relationship to MY_CommonProperty (the aggregation class). In the class diagram (Figure 1), the blue classes refer to part of strata objects for a better readability of the model.

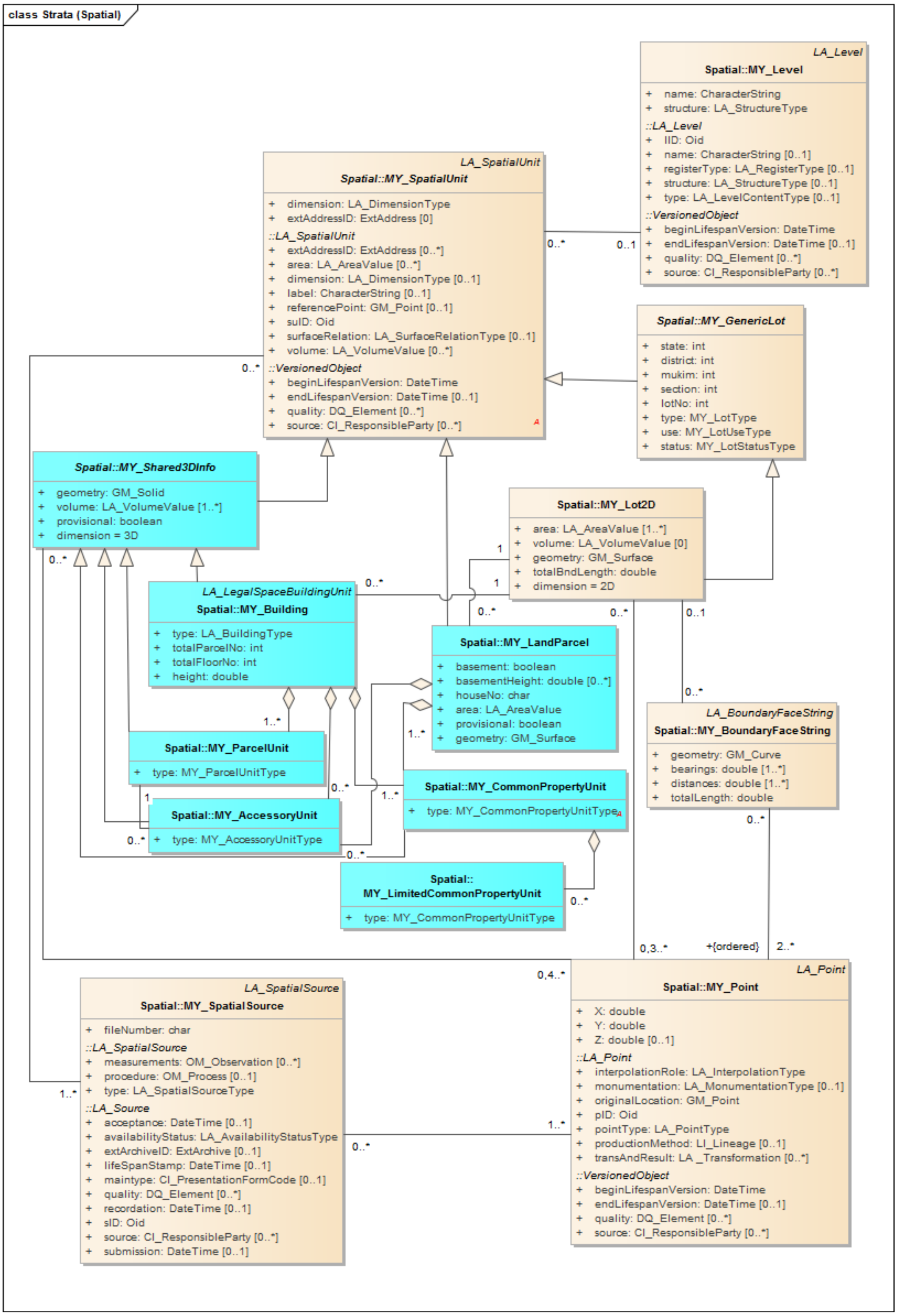

Figure 1: Details of spatial side of strata objects model

3.2 Administrative Part

The administrative part of the strata model contains Party and Administrative package (refer Figure 2). Main class of the party package is MY_Party class with its specialisation MY_GroupParty. There is an optional association class called MY_PartyMember. Basically, a party is a person or organisation that plays a role in a rights transaction. The organisation can be a company, a municipality or a state. A *group party* is any number of parties, forming together a distinct entity. A *party member* is a party registered and identified as a constituent of a group party. This allows the documentation of information to a membership (holding shares in right).

The administrative package concerns the abstract class MY_RRR (with its three concrete subclasses MY_Right, MY_Restriction and MY_Responsibility), MY_BAUnit and MY_AdministrativeSource.

A BAUnit is an administrative entity consisting of zero or more spatial units (parcels) against which one or more unique and homogeneous rights, responsibilities or restrictions are associated to the whole entity as included in the Land Administration System. An example of a BAUnit is a basic property unit with two spatial units with same RRRs attached (e.g. Federal Land Development Authority - FELDA). A settler can have two spatial unit (i.e. residential and farm land) with same RRRs attached. A BAUnit may play the role of a 'party' because it may hold a right of easement over another, usually neighbouring, and spatial unit.

One of the important foundations of LADM is the fact that all information in the system should originate from source documents and that the association to the source document is explicitly included. In case of administrative source documents (usually titles) there are associations with right, restriction and responsibility (RRR) and basic administrative unit. MY_AdministrativeSource associates with MY_RRR and MY_BAUnit. The strata model uses sID for administrative source. Basically, sID for administrative source is title number.

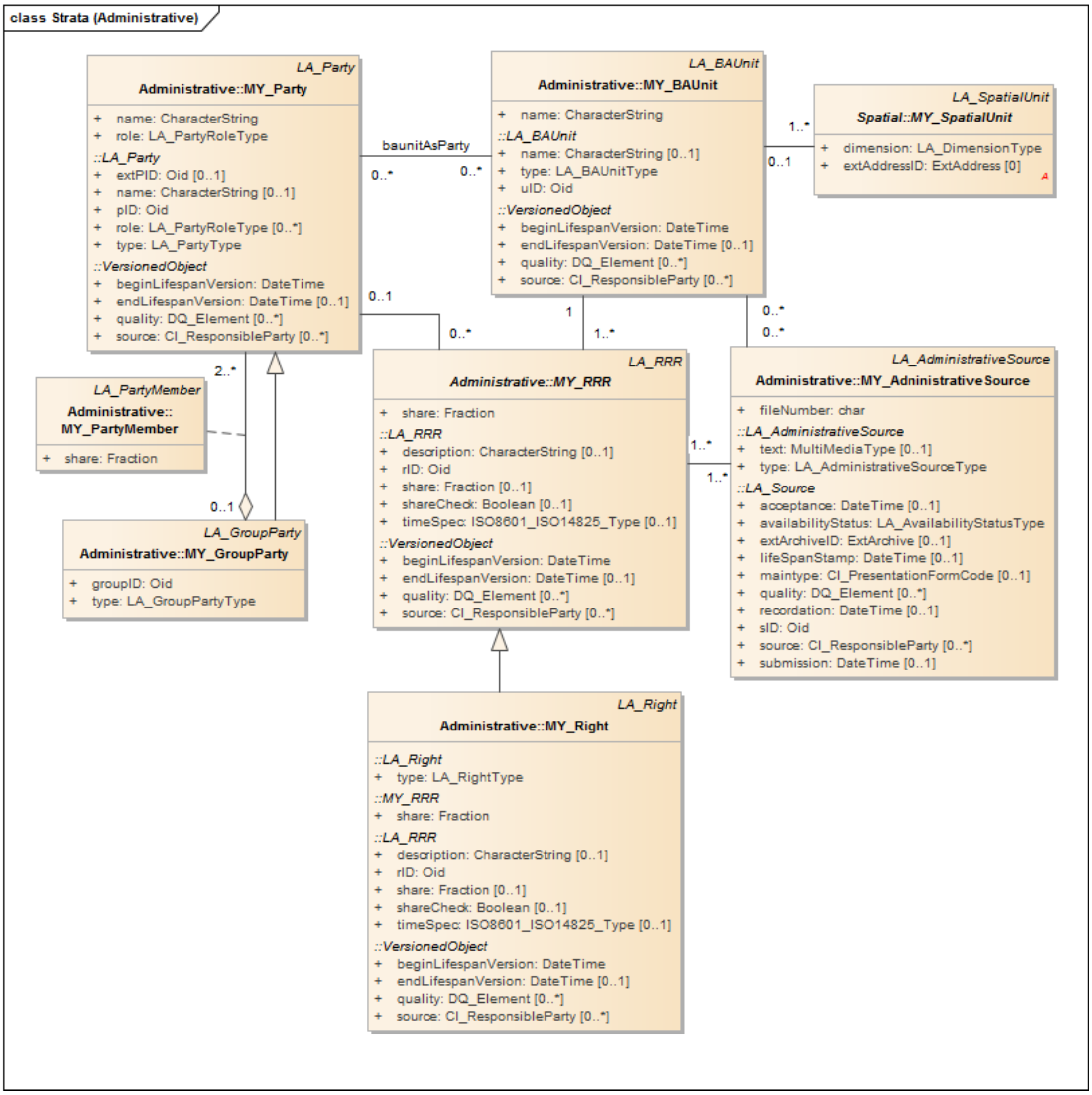

Figure 2: Details of administrative side of strata objects model

4. CONVERTING STRATA XML TO LADM

Some sample data from JUPEM (i.e strata XML and building plan) are converted into the model. The study area is at Perdana Parkcity project (refer Figure 3) in the state of Kuala Lumpur. Perdana Parkcity project is a mix development which contains one condominium with twenty seven storey and seventy six land parcels with three storey houses.

Figure 3: Study area

By analysis of the current XML strata data, it contains the following information: schema, block, '*tingkat*' or floor, parcel, accessory, common area and land parcel. Where, each information is contains their own attributes. Based on the developed strata objects model, block is refer to *MY_Building* class, parcel refer *MY_ParcelUnit* class, accessory refer to *MY_AccessoryUnit* class, common area refer to *MY_CommonPropertyUnit* class and land parcel refer to *MY_LandParcel* class. Two strata objects are missing (i.e. scheme and floor). However, it can be derived using Unique Parcel Identifier (UPI). For examples, UPI for parcel unit is 14000200062179(S)5016(B)M1(M)0(T)7(P)10 as highlighted in Figure 4. So, the scheme number for the parcel unit is 5016 and the '*tingkat*' or floor number is 7. The detail information for UPI can refer to Zulkifli et al., (2013).

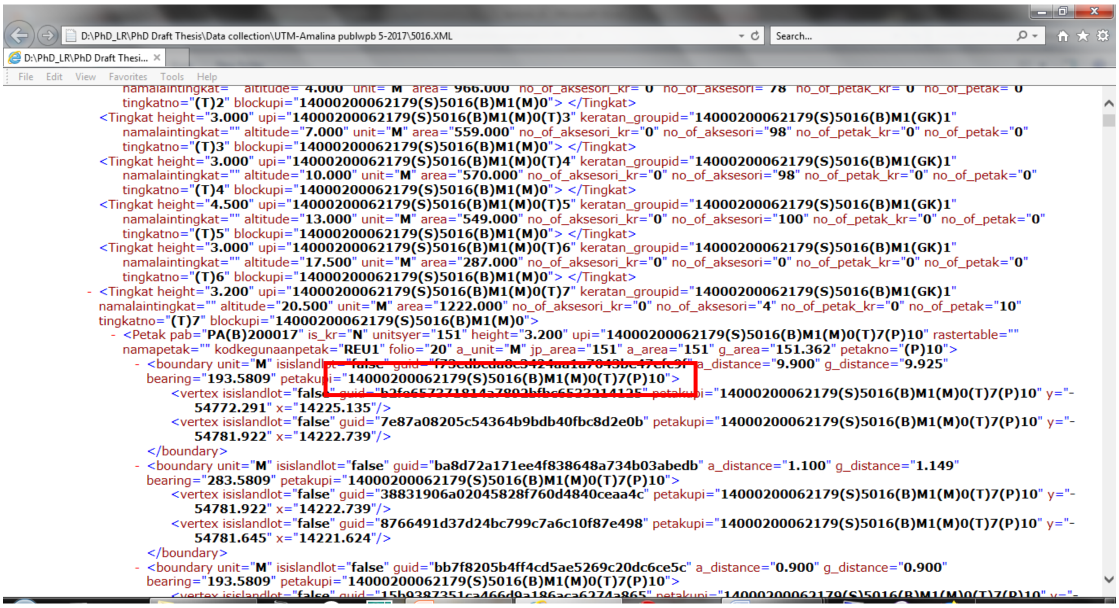

Figure 4: Strata XML

The Strata XML format used in this experiment is formatted in version 7.6. The conversion from Strata XML to LADM is done by implementing an intermediate mapfile, which contains information from origin terminology (XML) to destination (LADM). The mapfile also contains information such as parent and child which is important in LADM schema. The output of the converter is then used to import into database. In this experiment PostgreSQL is used. Figure 5 indicated the workflow of the experiment.

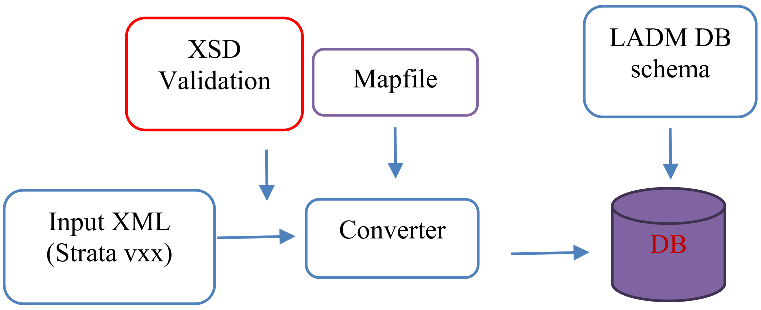

Figure 5: The workflow diagram of the conversation

The program is developed using C# NetCore initialized with desktop form. The input of the XML named Strata XML is validated via schema definition file (XSD). The input is then scanned via XDocument with the XSD validation. Validated XML will then be used as input in converter. Mapfile is also loaded into the program and conversion process is initialized based on the XML structure, which is from top to bottom. Noted that the database is already loaded with LADM compliant tables or schemas, which will be used to store the converted output. Brief snippet of mapfile is depicted in Figure 6. The mapfile determines the parent and child, the appropriate LADM container as well as its attributes.

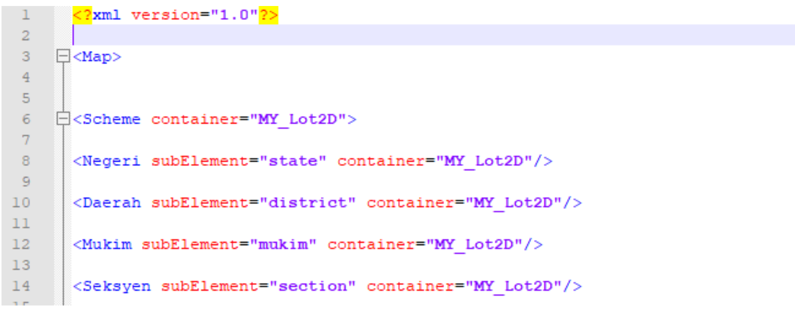

Figure 6: The mapfile snippet

As the Strata XML stored height information at parent level, and applies to entire parcel unit of the floor, the converter used such information to aggregate the levels and store as Z value for each corner of the parcel unit, in other words, the boundary face string of the parcel unit. The entire conversion is done without human intervention, and the result is shown in Figure 7. Note that the land parcel in the scheme, with some empty lots, showed in Figure 8. The GUI for the program is shown in Figure 9. The result in 3D is then viewed in QGIS.

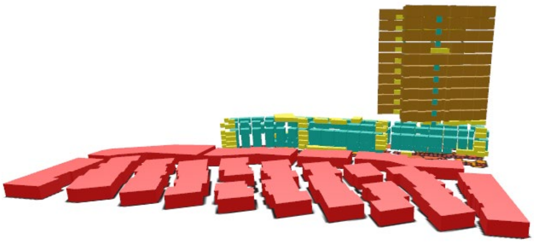

Figure 7: The entire scheme

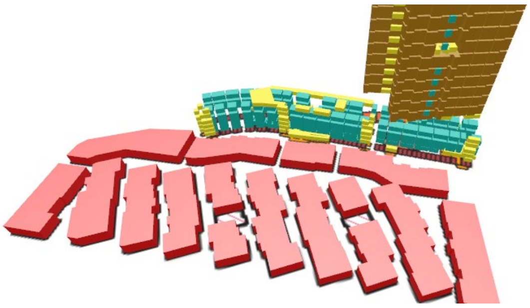

Figure 8: The entire scheme with an empty lot

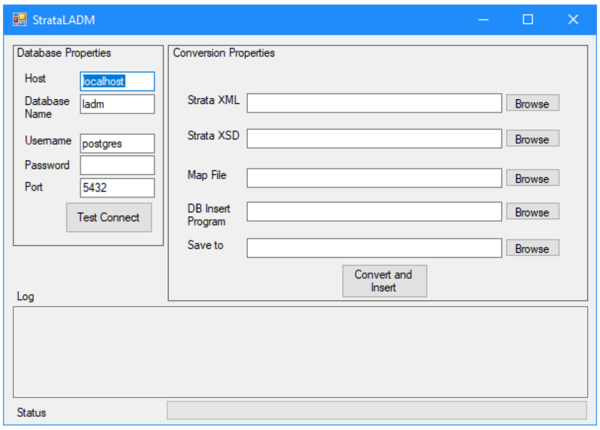

Figure 9: GUI of the conversion

5. PROTOTYPE DEVELOPMENT

This section describes the development of a prototype for the assessment of the conceptual model of strata objects – LADM based. According to LADM, the data type for Oid has two parts: the namespace and a local ID. An example of a possible namespace is lot2D.cadastre.jupem.my or point.cadastre.jupem.my. By adding this to the local ID, it becomes globally unique. However, within the system of JUPEM, it is not needed to add the namespace (as this is the same for all objects in the same table). Therefore, internally the local ID is enough for the various identifier values. The important aspect is that the ID's have to be unique for objects. Note that for a single object there may be multiple versions, which have the same ID, but can be differentiated via their beginDateTime attribute.

Each table has a Primary Key (PK), a combination of one or more attributes. The attribute value(s) of the PK must be unique for each entity. However, there can be different versions of an object (when some attributes are changed). This means for the same object, there are multiple records in the table with different begin and end date/times. To specify a unique record in the table, both ID and beginDateTime should be part of the primary key.

Each code lists class is implemented by their own table. The table name has the extension 'Type' added after the code list name of the conceptual model. The table for each code lists class has code list ID's (cID) and description attributes. As code list descriptions may be updated, they are also verioned, that is, they have beginDateTime and endDateTime attributes (and beginDateTime is part of primary key). So, we can manage and implement the code lists using Foreign Key attribute (cID). The code list attributes have Foreign Key to refer the attribute with the code list table. So, the list of code list for spatial and administrative part in the conceptual model is useful because we refer that code list using code list ID (cID) attribute as a Foreign Key.

Modelling tools, such as Enterprise Architect, offer automated conversions from the conceptual model Unified Modelling Language (UML) class diagram to the technical model. However, some manual fine-tuning of technical model is needed. Having the technical model, existing sample data from JUPEM (spatial) are converted into this structure and loaded in the database. The data from the Postgres database can be accessed using QGIS software for 3D visualisation and editing. The Structured Query Language (SQL) will be used to query and extract the data from the database with the prototype. The prototype has limited functionality as the main purpose is to assess the conceptual and derived technical model of the Malaysian LADM country profile. This means that it will not address multi-users aspect, not include large data sets, not include all tables (only most important tables and the tables for which there is data) and not develop a web-based interface for dissemination (just a desktop GIS interface).

Development of the prototype begins with conceptual of strata objects model. Thirty seven classes (refer Figure 10) from the strata model are selected to translate it into tables in the database schema. Many design decisions have been taken during the conversion of strata XML to LADM standard. Initial results or output of the prototype as illustrated in Figure 11.

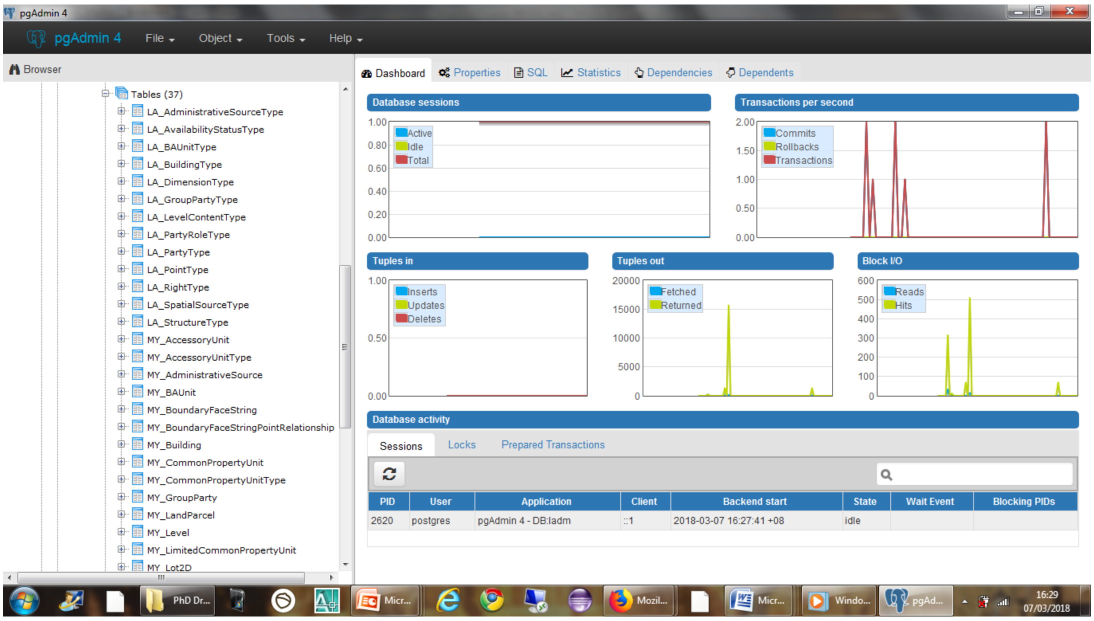

Figure 10: Postgres database

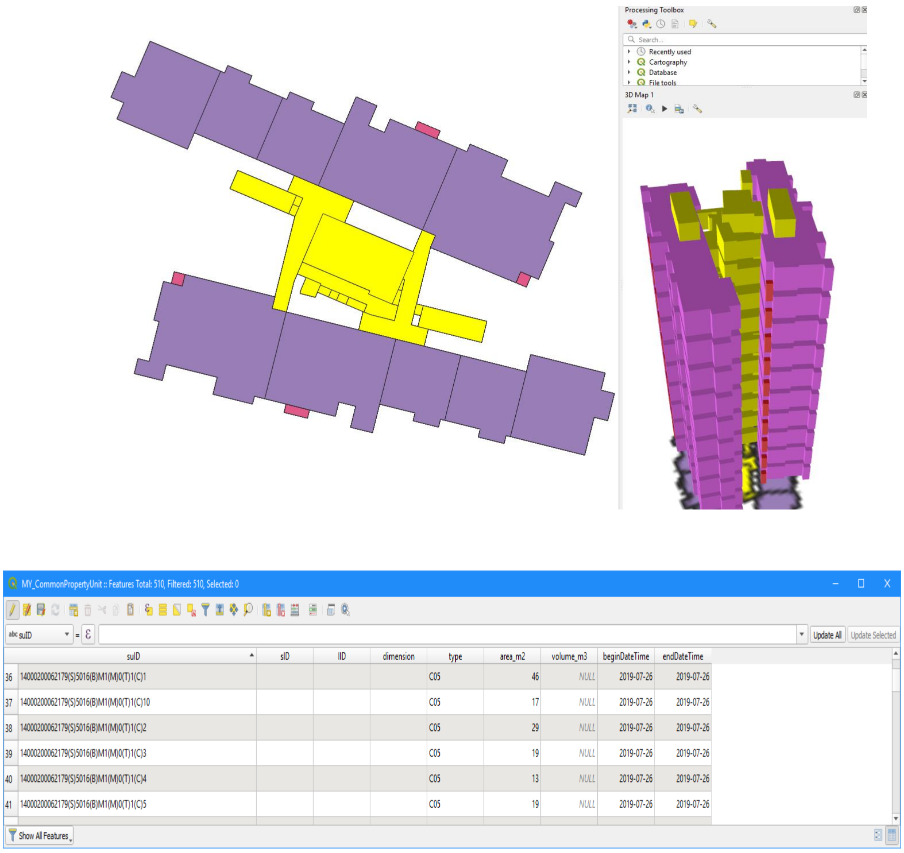

Figure 11: Data query and visualization of strata objects using QGIS

6. CONCLUSIONS

The contribution of this research is the formulation of this mapfile for the purpose of converting local industry strata scheme to LADM compliant datasets. This is important and essential to achieve both industrial demands in utilizing common scheme in daily business practices, while allowing standardization of data towards full implementation of LADM for the country as a whole. The mapfile is a transition and intermediate solution towards the potential full implementation of LADM in Malaysia. Enriching the mapfile for supporting the latest version of Strata XML allow seamless integration between systems and standards.

The outlook of this research is to develop a near-future prototype that covers all functionalities with large area and creating prototype with appropriate web-interface for JUPEM data accessibility.

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BIOGRAPHICAL NOTES

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Siew Chengxi Bernad is currently an entrepreneur venturing in GIS industry. He is a PhD graduate from Faculty of Geoinformation and Real Estate, Universiti Teknologi Malaysia in 2016. He specializes in GIS web services, SDI, system architectures, compression techniques and recently his topic of interest is in land administration. He established a company called Geotech Solutions Sdn Bhd in Malaysia, providing in-house developed spatial hosting and related services, as well as consultations in technology implementations and prototyping.

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