Development of a Prototype for the Assessment of the Malaysian LADM Country Profile

Nur Amalina ZULKIFLI, Alias ABDUL RAHMAN, Hasan JAMIL, TENG Chee Hua, TAN Liat Choon, LOOI Kam Seng, CHAN Keat Lim, Malaysia and Peter VAN OOSTEROM, The Netherlands

SUMMARY

During the last couple of years, the potential of 3D and Land Administration Domain Model (LADM, ISO 2012) based cadastral registration in Malaysiahas been investigated and described in several papers, and presented at various International Federation of Surveyor (FIG) meetings. Based on these preparations, a two day workshop and additional meeting between Research and Development(R&D) staff from Department Survey and Mapping Malaysia (JUPEM) and Universiti Teknologi Malaysia (UTM) has resulted in a proposal for a comprehensive LADM country profile supporting 2D and 3D cadastral registration in Malaysia. This conceptual model consists ofseveral novel aspects for Malaysia: 3D representations (incl. legal spaces around utilities), full version management, linking of database information and source documents, and basic property units (grouping of spatial units in one basic administrative unit with same rights attached). In order to assess the new conceptual model, before taking further implementation decisions, a prototype system was developed to discover the possibilities and limitations of the conceptual model. Experience from the prototype development will be used to further improve the conceptual model, before actual implementation. The steps in developing this prototype include:
1. deriving the technical model (Oracle spatial) from the conceptual model,
2. convert some (and/or create) sample JUPEM/land office data into model, and
3. develop prototype (based on MicroStation) to view and edit.

During the development of the conceptual model based on LADM, many design decisions have been taken and documented, resulting in the Malaysian country profile (Zulkifli et al 2014). Next, again many design decisions have to be taken to develop the database schema during the conversion from conceptual to technical model. In this phase the nature of the design decision is more technical and closer to actual implementation.

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Key words: database, technical model, LADM, country profile, 3D cadastre

1. INTRODUCTION

Many countries such as Poland, Republic of Korea and Croatia have proposed country profile based on LADM as reported by Bydlosz (2013), Kim et al (2013) and Vucic et al (2013). Some earlier preparation activities on LADM for Malaysia were initially reported by the following papers (Hassan and Abdul Rahman, 2010; Abdul Rahman et al, 2011; Tan and Looi, 2013 and Zulkifli et al, 2013). According to Lemmen (2012), the presentation of country profiles based on this standard have two purposes – first, is to understand the structure and relationships within the individual country land administration system; the second purpose is to show examples of modelling solutions that can be useful in building profiles for other countries. In Malaysia, an effort for LADM initiative has been proposed by a group of JUPEM cadastre division and UTM researchers (Zulkifli et al 2014). Malaysian LADM country profile is divided into two parts - administrative and spatial; referring to respectively Annex A.1 and A.2 of (Zulkifli et al 2014).. This paper describes the development of a prototype for the assessment of the Malaysian LADM country profile. 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) and Land Office (legal, administrative) are converted into this structure and loaded in the database. Finally, the data from the Oracle database can be accessedusing Bentley MicroStation software for 2D and 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 (locking, security, authorization, etc.), not include large data sets, not include all tables (only most important tables and the tables for which there is data), not develop a web-based interface for dissemination (just a desktop GIS interface), etc.

This paper is organized as follows: Section 2 describes some design decisions which have been taken during the conversion from conceptual model to technical model. The conversion

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of sample data from JUPEM and land office into the model is discussed in Section 3. Section 4, presents the development of the prototype based on MicroStation. Finally, the conclusions are presented in Section 5.

2. DERIVATION OF TECHNICAL FROM CONCEPTUAL MODEL

In this section the various technical design decisions will be elaborated on. The starting point is the conceptual model (Zulkifli et al 2014) as developed earlier. In Annex A.1 and A.2 of (Zulkifli et al 2014) the UML class diagrams of this earlier designed conceptual model are given. Some example classes are MY_Lot2D (spatial unit with 2D topology description), MY_BoundaryFaceString (2D boundaries of the lots implying vertical faces), MY_Point (2D or 3D points obtained from spatial source documents), MY_ParcelUnit (3D polyhedral description of an apartment unit in a building), etc. The target is a database schema (in Oracle Spatial) to implement the land administration system based on the LADM. Annex A of this paper contains a symbolic description of the database schema. A class in the UML model, normally corresponds to table with same name in the database schema. Additionally, there are also views (their names end with 'View'), tables for code lists (their names end with 'Type'), and additional tables for representing relationships in case of a many-to-many relation between two classes (their names end with 'Relationship'). Subsection 2.1 discusses primary keys, versioning and foreign keys. The next subsection (2.2) addresses topics related to constraints, derived attributes and the multiplicity of attributes. The (spatial and non-spatial) indexing and clustering are the topic of subsection 2.3. Finally, subsection 2.4 elaborates on the technical parts of the 2D topology implementation.

2.1 Identifiers (ID), Primary Keys, Versioning and Foreign Keys

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) and by adding this to the local ID, it becomes globally unique (as nobody else is allowed to assign ID's in this name space). However, within the system of JUPEM (internally), 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. For administrative tables, the primary key is used for physically clustering (sorting the records in this order) to make access efficient and not needing an extra indirection (and storage) of an index. For spatial table, the (derived) geometry is used for spatially clustering the records in the table. For fast selection and easy of a record based on ID, an additional B-tree index is

defined on this attribute.

Foreign Key (FK) is used to refer to the PK attribute(s) within another table. In Annex A of this paper it is indicated whether an attribute is Primary Key and in case it is a multi-attribute Primary Key, then the attributes get a sequence number as labeled: PK1, PK2, etc. Also Foreign Keys are indicated. Note that only the ID part is stored in the Foreign Key and not the beginDateTime part as this would cause a cascading effect in case of an object update and all other objects referring to this object (and objects referring to the referring object, and so on), which is the case in a topology structure (van Oosterom 1997). In one table, we can have multiple Foreign Key attributes to refer to different tables. The data type of the Foreign Key attribute is equal to the corresponding Primary Key attribute. In some cases there is a B-tree on the FK attribute to enable efficient searching in reverse direction; e.g. on the rightFace_suID and on the leftFace_suID in table MY_BoundaryFaceString, there are both B-tree indices created. This enables efficiently finding all edges (MY_BoundaryFaceString) for a given face (MY_Lot2D without storing (variable) length references from MY_Lot2D to MY_BoundaryFaceString (refer Annex A).

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.

2.2 Constraints, Derived Attributes and Multiplicity of Attributes

There are many types of constraints: e.g. primary key must be unique, endDateTime > beginDateTime, end date of previous version must be equal to start of next version, sum of shares must equal to 1, boundary of lot must be closed, boundaries may not intersect (topology constraints), MY_Level constraint to organize the different types of spatial unit in different levels (e.g. level 2 for 2D lots, level 3 for 3D lots), and so on. Note that instead of directly implementing the versioning support in the model with own attributes (beginDateTime and endDateTime) it would also be possible to use database built-in functionality for this purpose; for example, Oracle's workspace manager to model and manage versions of objects. Drawback is that solution becomes less generic (more Oracle specific) and also workspace manager offers more functionality/ complexity which does not seem relevant at the moment. Advantage of using the Oracle solution is that less has to be developed (e.g. the constraints), and also that other software may know the Oracle approach and be able to use this (e.g. Bentley Microstation). For time being, it was decided to use the generic solution directly based on attributes beginDateTime and endDateTime according to the ISO 19152 versioning.

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To realize derived attributes, Structured Query Language (SQL) 'create view' was used. The function used in the 'create view' statement derives the attributes from another table or attribute. For an example, we have to derive geometry, bearings, distances and totalLenghts attributes in MY_Point table. The advantage of using a view is that these derived attributes are not stored, but for the users it is easy as the views look the same manner as normal tables. Besides saving storage space, the advantage is that this cannot cause inconsistencies, which is the danger when these derived attributes would be explicitly stored. There are standard functions in Oracle to derive the attribute. For example, SDO_GEOM.LENGTH function can be used to derive length attribute and add this to other attributes of MY_BoundaryFaceString. If there is no standard function in Oracle to derive the attribute (for example the varray attributes such as bearings, distances within a polyline), we have to create our own function by programming. It was decided to give the views the same name as their base table, but extended with the postfix 'View'; e.g. MY_BoundaryFaceStringView; see Annex A.

As in LADM Malaysian country profile, we have multiple types of area/volume attributes (surveyed, official and calculated) in MY_Lot2D, MY_Lot3D, MY_LandParcel, MY_Customary and MY_ReservedLand, the multiplicity of this attribute in Malaysian LADM country profile is 'many'. There are at least 3 different ways to implement this:
1. additional table for this multiple attribute,
2. use varray to represent all values or
3. have a fixed number of area/volume attribute (e.g. 3 or 4 and indicate in name of attribute which area/volume type is intended).

To realize the multiplicity of attributes, we are analyzing the specific situation and select the best solution. For example, we use multiple attributes for the various area types in the database schema in case of the area attribute in MY_Lot2D: officialArea_m2, calculatedArea_m2 and surveyedArea_m2. This was considered the most simple and sufficient solution. In another situation of variable length multiplicities implementation, we decided to use varray data structure in other situations; e.g. the basementHeights in MY_LandParcel. But also in derived attributes the varray can be used for returning attributes with variable multiplicity; e.g. in the view MY_BoundaryFaceString View, the derived attributes bearings and distances are variable length (while the derived attribute totalLength is a single value and derived using the sdo_geom.length function in Oracle).

2.3 Indexing and Clustering

In order to enable efficient searching base on selecting on attribute value, an index is created in the database. This can be done for both spatial (R-tree index) and non-spatial (B-tree index) data. For the administrative class, we have created a B-tree index for party reference (pID) attribute in MY_Right, MY_Restriction, MY_Responsibility and MY_Mortgage. We also created a B-tree index for rightFace_suID and leftFace_suID attributes in MY_BoundaryFaceString table (spatial class). We also created an R-tree index on the geometry attributes in the spatial tables.

Primary Key ID's attributes in the various tables for administrative data are used to physically organize the data in so called index organized tables. In this manner one additional B-tree

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index is saved, which is making the system more compact and efficient. The (derived) geometry in each spatial class is used to index the spatial object based on geometry type using the R-tree index. Remember that Oracle Spatial has various geometry types; e.g. MY_LandParcel has Oracle's gtype 2003 (2D polygon), and strata object has Oracle's gtype 3007 (3D multipolygon). In case of topology (e.g. MY_Lot2D) the geometry has to be derived first (as specified in the view MY_Lot2DView) and then this can be used to spatially index the table. It is also under investigation, how to spatially cluster these tables.

2.4 2D Topology Structure

The reason to have edges (MY_BoundaryFaceString) which are not per se straight line segments, but which can be polylines, is to avoid redundancy. As otherwise same left/right topology information has to be repeated for every line segment (making the storage bigger, slower the system, and a source for possible inconsistencies). The end pointsof an edge, play an important role in the topology of the model and therefore it is good to be able to differentiate them from intermediate points.

In the topological model (refer to Annex B of (Zulkifli et al 2014)), an intermediate point is incident with exactly 2 line segments. Meanwhile, the node (end point) is incident with 3 or more line segments (in as many edges). The intermediate points and end point (nodes) can be differentiated using MY_BoundaryFaceStringPointRelationship table. This is a new table created because of the many to many relationships between MY_BoundaryFaceString and MY_Point tables. MY_BoundaryFaceStringPointRelationship has 5 attributes which are bfsID (FK), pID (FK), sequenceNr, beginDateTime and endDateTime. The combination of bfsID and pID (and beginDateTime) is a Primary Key of this table. There is a convention that the sequenceNr of the begin point (node) in the edge should be 1 and that subsequent points get sequenceNr's 2, 3, etc. until the end point (node) of the edge which gets the special sequenceNr value of 0. The intermediate points used only once meanwhile, nodes (begin or end point) are used multiple times in this table. Several other constraints are relevant: e.g. if there is a point with sequence number x (e.g. 5), then there should also be points with lower sequence numbers < x (e.g. 0,1,2,3 and 4 in the case of example value 5), also line segments may not intersect (not within same edge, but also not with other edges), which is quite a different type of constraint.

The topology implementation is based on our own structure because this can be custom made for needs and also independent with respect to database platform (i.e. could also be applied when using another database). The alternative would be to use the SDO_TOPO package from Oracle (available version 11 and higher). Advantage of using SDO_TOPO is that less own development is needed.

3. CONVERSION OF SAMPLE DATA INTO THE MODEL

Some sample data from JUPEM and land office are converted into the model. Database construction is based on Oracle spatial. The study area is at World Youth Foundation (WYF) building in the state of Melaka and some land parcels around that building. WYF is a

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commercial building with four storeys. The building is for 3D cadastral registration system meanwhile, the land parcel around that building is for 2D cadastral system based on LADM. In Malaysian LADM country profile, land parcel (e.g. MY_Lot2D) is based on 2D topology with references to shared boundaries. There is currently no topology structure used in 3D registration objects (e.g. MY_Lot3D and MY_Building). For MY_Lot2D, there are three important tables involve to represent 2D topology they are MY_Point, MY_BoundaryFaceString and MY_Lot2D. Figure 1, 2 and 3 show how to create the tables and subsequently insert data in MY_Point, MY_BoundaryFaceString, and MY_Lot2D tables. Annex B of (Zulkifli et al 2014) shows the topological structure data of the 2D lot (note that lot numbers 040108000015662 and 040108000015664 are symbolically labelled as faces F1 and F5).

```
CREATE TABLE  MY_POINT (
pid varchar2(10) primary key,
sid varchar2(25) REFERENCES my_spatialsource(sid),
survey_point mdsys.sdo_geometry,
transformation varchar2(250),
map_point mdsys.sdo_geometry,
type varchar2(5) REFERENCES la_pointtype(cid),
begin_date_time timestamp,
end_date_time timestamp);

----------------------------------------------------------------------------

INSERT INTO MY_POINT VALUES (
'N1',
'04-42351',
MDSYS.SDO_GEOMETRY (2001,24571,MDSYS.SDO_POINT_TYPE (23664.166398,12426.942536,NULL),NULL,NULL),
'NULL',
MDSYS.SDO_GEOMETRY (2001,24571,MDSYS.SDO_POINT_TYPE (23764.739732,12526.967747,NULL),NULL,NULL),
'PN01',
'01-JAN-14 08:10:04.20',
'');
```

Figure 1: Create table and insert data in MY_Point table using Oracle

```
CREATE TABLE MY_BOUNDARYFACESTRING (
bfsid varchar2(10) primary key,
first_right_edge_bfsid varchar2(10) REFERENCES my_boundaryfacestring(bfsid),
last_left_edge_bfsid varchar2(10) REFERENCES my_boundaryfacestring(bfsid),
right_face_suid varchar2(16) REFERENCES my_lot2D(suid),
left_face_suid varchar2(16) REFERENCES my_lot2D(suid),
begin_date_time timestamp,
end_date_time timestamp);

------------------------------------------------------------------------

INSERT INTO MY_BOUNDARYFACESTRING VALUES (
'E1',
'-E10',
'+E2',
'04010800015664',
'04010800015662',
'01-JAN-14 08:20:12.44',
'');
```

Figure 2: Create table and insert data in MY_BoundaryFaceString table using Oracle

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```
CREATE TABLE MY_LOT2D (
suid varchar2(16) primary key,
sid varchar2(25) REFERENCES my_spatialsource(sid),
lid varchar2(25) REFERENCES my_level(lid),
state varchar2(2),
district varchar2(2),
mukim varchar2(2),
section varchar2(3),
lot_no varchar2(7),
type varchar2(5) REFERENCES my_lottype(cid),
use varchar2(5) REFERENCES my_lotusetype(cid),
status varchar2(2) REFERENCES my_lotstatustype(cid),
official_area_m2 dec(7,3),
calculated_area_m2 dec(7,3),
surveyed_area_m2 dec(7,3),
dimension varchar2(5) REFERENCES la_dimensiontype(cid),
begin_date_time timestamp,
end_date_time timestamp);

----------------------------------------------------------

INSERT INTO MY_LOT2D VALUES (
'04010800015662',
'04-42351',
'04010800015662L2',
'04',
'01',
'08',
'000',
'15664',
'L01',
'LU02',
'99',
'15243',
'15242',
'15244',
'DT03',
'01-JAN-14 08:30:10.05',
'');
```

Figure 3: Create table and insert data in MY_Lot2D table using Oracle

```
CREATE TABLE MY_PARCELUNIT (
suid varchar2(73) primary key,
sid varchar2(25) REFERENCES my_spatialsource(sid),
lid varchar2(25) REFERENCES my_level(lid),
dimension varchar2(5) REFERENCES la_dimensiontype(cid),
type varchar2(5) REFERENCES my_parcelunittype(cid),
area_m2 dec(7,3),
volume_m3 dec(10,3),
geometry mdsys.sdo_geometry,
begin_date_time timestamp,
end_date_time timestamp);

---------------------------------------------------------------------------------

INSERT INTO MY_PARCELUNIT VALUES (
'04010800015662(S)846(B)M1(M)1(T)1(P)1',
'PA(B)42350-01',
'04010800015662(S)846(B)M1(M)1(T)1(P)1L4',
'DT04',
'CBU7',
'206',
'803',
MDSYS.SDO_GEOMETRY(3007,24571,NULL,
MDSYS.SDO_ELEM_INFO_ARRAY(
1,1003,1,
16,1003,1,
31,1003,1,
46,1003,1,
61,1003,1,
76,1003,1),
MDSYS.SDO_ORDINATE_ARRAY(
23763.508701,12534.314343,0.193868,23763.508701,12534.314343,0,23763.238999,12534.084021,0,
23763.238999,12534.084021,0.193868,23763.238999,12534.314343,0.193868,23763.238999,12534.084021,0.193868,
23763.238999,12534.084021,0,23764.154808,12533.005249,0,23764.154808,12533.005249,0.193868,
23763.238999,12534.084021,0.193868,23764.42451,12533.235571,0.193868,23764.42451,12533.235571,0,
23764.154808,12533.005249,0,23764.154808,12533.005249,0.193868,23764.42451,12533.235571,0.193868,
23763.508701,12534.314343,0.193868,23763.508701,12534.314343,0,23764.42451,12533.235571,0,
23764.42451,12533.235571,0.193868,23763.508701,12534.314343,0.193868,23764.42451,12533.235571,0,
23763.508701,12534.314343,0,23763.238999,12534.084021,0,23764.154808,12533.005249,0,
23764.42451,12533.235571,0,23764.42451,12533.235571,0.193868,23763.508701,12534.314343,0.193868,
23763.238999,12534.084021,0.193868,23764.154808,12533.005249,0.193868,23764.42451,12533.235571,0.193868)),
'01-JAN-14 10:15:30.26',
'');
```

Figure 4: Create table and insert data in MY_ParcelUnit table using Oracle

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MY_Lot2D represent 2D cadastral area object (polygon, GTYPE = 2003), and MY_ParcelUnit represent 3D cadastral volume objects (e.g MY_ParcelUnit) are stored by multipolygon method (GTYPE = 3007). Oracle spatial also has a solid type (GTYPE = 3008), which in theory is preferred above the multipolygon for handling the solid type, but only available in more reference versions of Oracle spatial, therefore the multipolygon was used instead (which will also work on older versions). Figure 4 shows how to create table and store 3D cadastral data using Oracle spatial.

4. THE PROTOTYPE FRONTEND DEVELOPMENT

After creating the database schema and loading sample data, the prototype frontend development is based on Bentley Microstation. Using this application, the query is conducted via the visual SQL Query Builder. The required functionality for assessing the model includes:
- styling specifications (colour, line type, etc.) and draw 2D simple feature geometry; e.g. MY_LandParcel2D,
- styling and drawing specifications for 2D topology; e.g. MY_Lot2D,
- zooming and panning in 2D of displayed map,
- styling and drawing specifications for 3D simple feature geometry; e.g. MY_ParcelUnit,
- zooming and panning in 3D of displayed map,
- making (SQL) selection based on spatial condition; e.g. find all lot within 50 meter from given point and highlight these on map and show them in selected table,
- making (SQL) selection based on non-spatial condition; e.g. find all lots created after 10 December 2013 and highlight these on map and show them in selected table,
- make a combined spatial and non-spatial selection,
- spatial joining; e.g. find all building within 5 meters of land parcel with area > 500 m^2,
- 2D editing of simple geometry feature with versioning; e.g. MY_LandParcel,
- 2D editing of topology structure feature with versioning; e.g. MY_Lot2D,
- 3D editing of simple geometry feature with versioning; e.g. MY_ParcelUnit.

In general, the prototype development consists of several steps, namely (see Figure 5);
- create Malaysian LADM country profile (conceptual model),
- derive Database schema (technical model),
- populate Oracle Spatial (convert and load the data), and
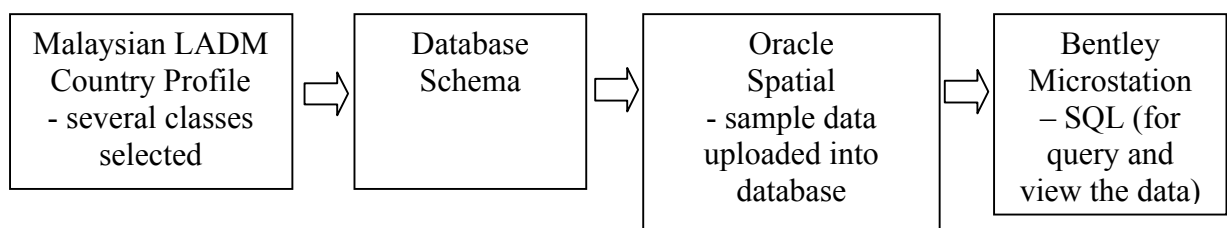- develop Bentley Microstation frontend (view and edit the data)

Malaysian LADM Country Profile - several classes selected	Database Schema	Oracle Spatial - sample data uploaded into database	Bentley Microstation – SQL (for query and view the data)

Figure 5: The four steps of the prototype development

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Development of the prototype begins with Malaysian LADM country profile. Several classes (i.e. MY_2DLot, MY_BoundaryFaceString, MY_Point, MY_BoundaryFaceStringPoint-Relationship and MY_ParcelUnit) from the country profile are selected to translate it into tables in the database schema. Many design decisions have been taken during the conversion of country profile (i.e. conceptual model) to database schema (i.e. technical model). Then, the data is uploaded into Oracle Spatial database. Bentley Microstation is used to visualise the geometry and query using SQL. As discussed in Section 1, this prototype has limited functions and only covers small area for the assessment of the Malaysian LADM country profile. Initial results or output of the prototype as illustrated in Figure 6 and 7.
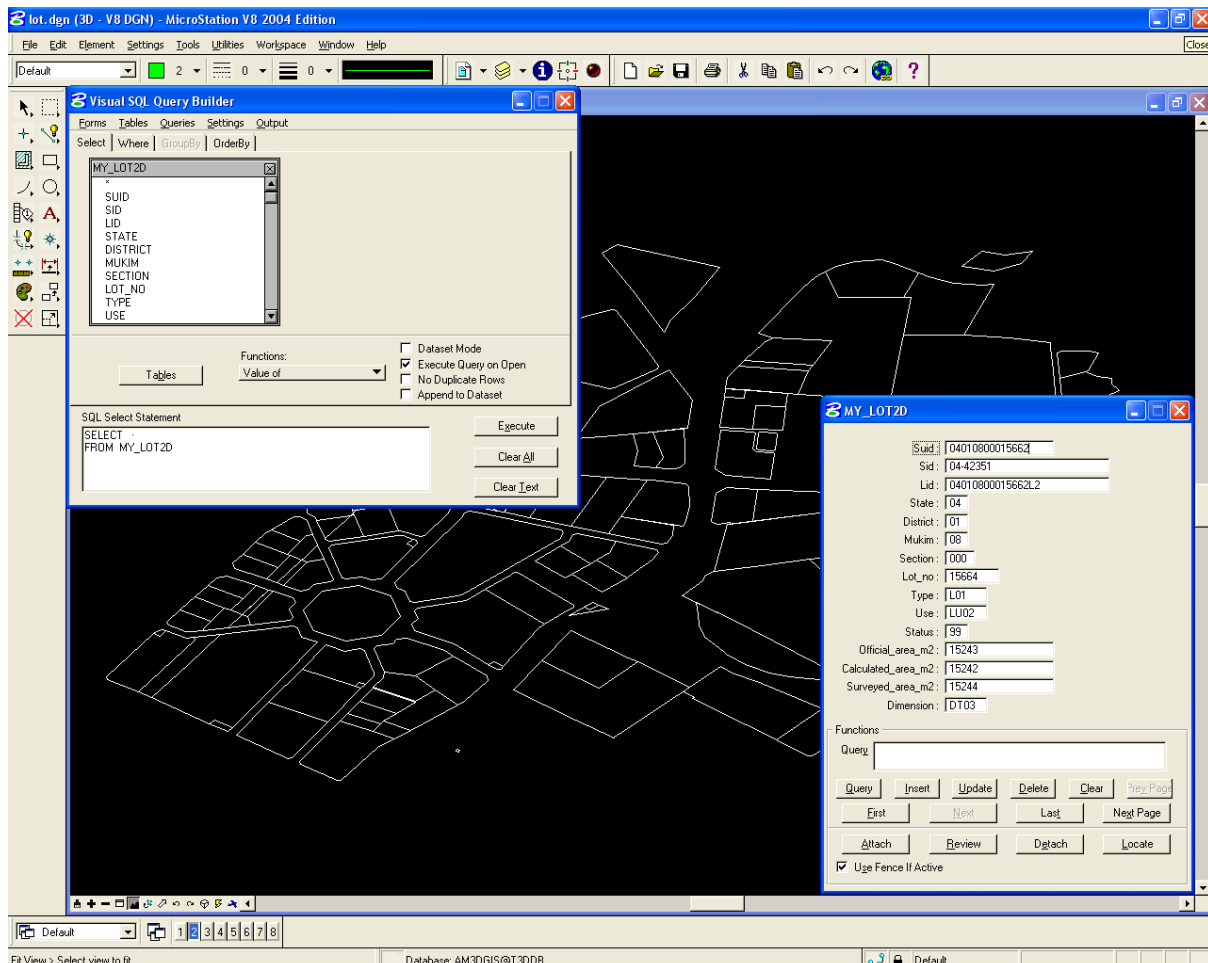

Figure 6: 2D data query and visualisation of MY_Lot2D using Bentley Microstation

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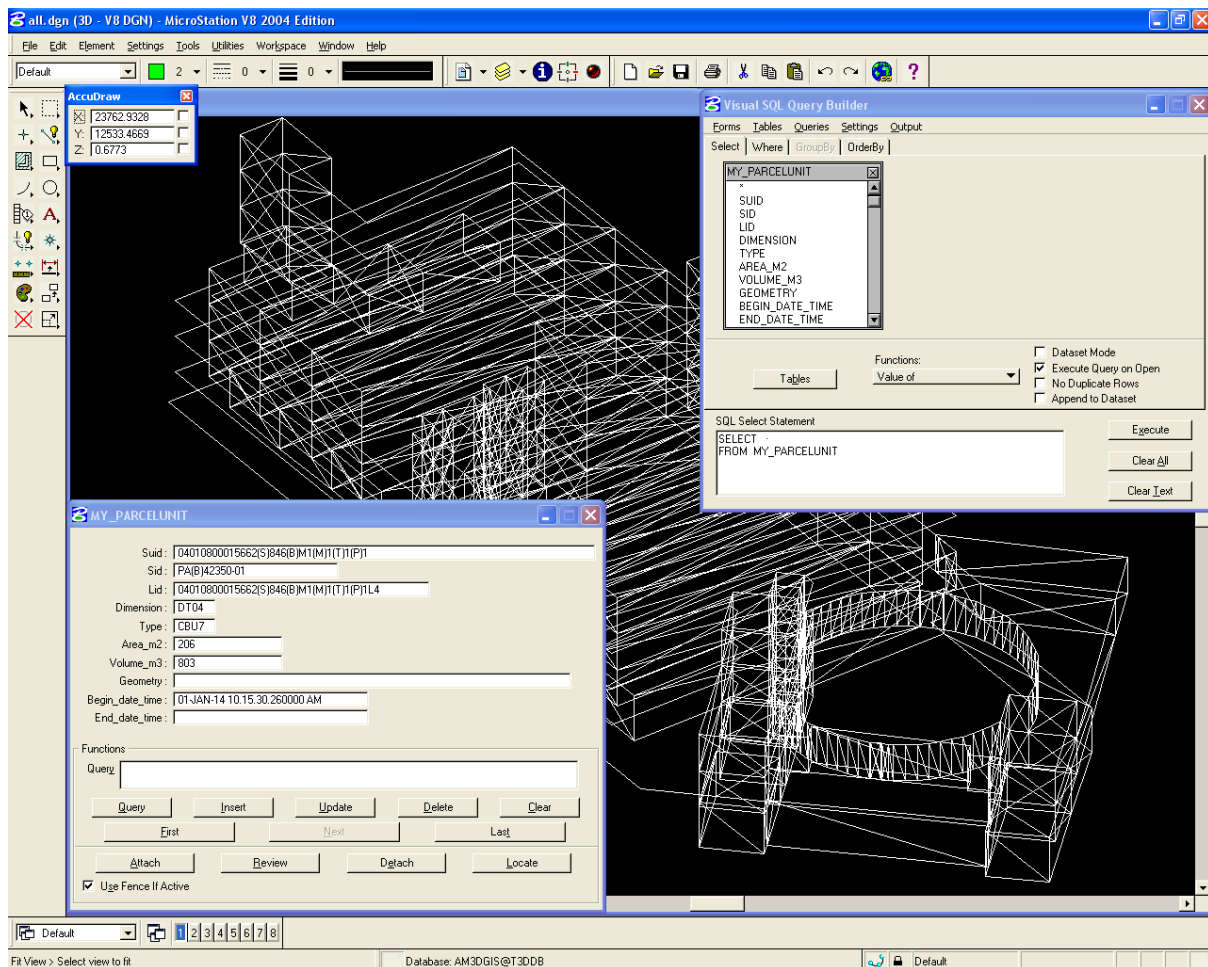Kuala Lumpur, Malaysia 16 – 21 June 2014

Figure 7: 3D data query and visualisation of MY_ParcelUnit using Bentley Microstation

5. CONCLUSIONS

This paper describes the prototype development based on Malaysian LADM country profile, which has been described and elaborated in other paper also at the same FIG 2014 conference (Zulkifli et al 2014). Many technical design and implementation decisions have been elaborated (refer to Section 2) during the conversion of country profile to database schema (technical model). The current prototype only covers 2D lots and 3D strata objects and the remainder of the classes (tables) will be dealt with at later development stage due to the extensive nature of country profile. In this assessment, sample data from Malaysian national mapping agency were utilized. We anticipated this prototype exercise serves as early direction for Malaysian LADM initiative and probably will generate better awareness. During the development of the technical model, also some minor omissions in the conceptual model were detected and corrected. The content of the code lists was improved (for example of LA_MortgageType, LA_BAUnitType, and LA_RestrictionType), a missing code list was

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added with content (LA_AvailabilityStatusType indicating the status of source documents in the archive). Also, the MY_LandParcel got specified an explicit geometry attribute of type GM_Surface (refinement of the inherited geometry description from the generic LA_SpatialUnit) and constraints were added to specify that land parcels may not overlap and must be inside a lot. However, the overall assessment of the conceptual model based on the developed prototype is positive: the Malaysian LADM country profile is feasible and covers well the required 2D and 3D functionality for representation spatial units.

The outlook of this research and subsequent development is as follows, realization of a near-future prototype that covers all functionalities with large area, development of regulations/formats for digital certified plans with 3D objects, redesign XML exchange formats for LADM based on Malaysian data, and creating prototype with appropriate web-interface for JUPEM/land office data accessibility.

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ANNEX A: Database schema

Database schema for this prototype development only covers MY_2DLot (create table), MY_2DLot (create view) MY_BoundaryFaceString (create table), MY_BoundaryFaceString (create view), MY_Point (create table), MY_Point (create view), MY_BoundaryFaceStringPointRelationship and MY_ParcelUnit. The white table refers to normal classes, blue table refer to create view classes (derived attributes) and yellow table refer to relationship classes (n-to-m relationship).

MY_Lot2D - create table	suID (PK1) - B-tree index	Varchar2 (16)	ID's of the 2D lot = *face* (UPI)
	sID (FK) - ref MY_SpatialSource (sID)	Varchar2 (25)	ID's of spatial source (Certified Plan)
	lID (FK) - ref MY_Level (lID) - constraints	Varchar2 (25)	ID's of the level (MY_Level.name = 'level 2')
	state	Varchar2 (2)	State of the 2D lot
	district	Varchar2 (2)	District of the 2D lot
	mukim	Varchar2 (2)	Mukim of the 2D lot
	section	Varchar2 (3)	Section of the 2D lot
	lotNo	Varchar2 (7)	Lot number of the 2D lot
	type (FK) - ref MY_LotType (cID)	Varchar2 (5)	Type of the 2D lot

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	use (FK) - ref MY_LotUseType (cID)	Varchar2 (5)	Use of the 2D lot
	status (FK) - ref MY_LotStatusType (cID)	Varchar2 (2)	Status of the 2D lot
	officialArea_m^2	Dec (7,3)	Official area of the 2D lot
	calculatedArea_m^2	Dec (7,3)	Calculated area of the 2D lot
	surveyedArea_m^2	Dec (7,3)	Surveyed area of the 2D lot
	dimension (FK) - ref LA_DimensionType (cID)	Varchar2 (5)	Dimension of the 2D lot
	beginDateTime (PK2)	Date	Begin lifespan version
	endDateTime - constraints	Date	End lifespan version (EndDate > BeginDate)
MY_Lot2DView - create view select *,	geometry - clustering - R-tree index	Mdsys.sdo_geometry	Geometry of 2D Lot
	totalBndLength	Dec (7,3)	Total boundary length of 2D Lot
MY_Boundary-FaceString - create table	bfsID (PK1) - B-tree index	Varchar2 (10)	ID's of the baundary face string = *edge*
	firstRightEdge_bfsID (FK) - ref MY_BoundaryFaceString (bfsID)	Varchar2 (10)	Topology reference to *first right edge* (signed&ordered)
	lastLeftEdge_bfsID (FK) - ref MY_BoundaryFaceString (bfsID)	Varchar2 (10)	Topology reference to *last left edge* (signed&ordered)
	rightFace_suID (FK) - ref MY_Lot2D (suID) - B-tree index	Varchar2 (16)	Topology reference to *right face*, MY_Lot2D
	leftFace_suID (FK) - ref MY_Lot2D (suID) - B-tree index	Varchar2 (16)	Topology reference to *left face*, MY_Lot2D
	beginDateTime (PK2)	Date	Begin lifespan version
	endDateTime - constraints	Date	End lifespan version (EndDate > BeginDate)
MY_Boundary-FaceStringView - create view	geometry - clustering - R-tree index	Mdsys.sdo_geometry	Geometry of the boundary face string

select *,	bearings	Varray(Dec (7,4))	Bearings of the boundary face string
	distances	Varray(Dec (7,3))	Distances of the boundary face string
	totalLength	Dec (7,3)	Total length of the boundary face string
MY_Point - create table	pID (PK1) - B-tree index	Varchar2 (10)	ID's of the point
	sID (FK) - ref MY_SpatialSource (sID)	Varchar2 (25)	ID's of the spatial source\
	surveyPoint	Mdsys.sdo_geometry	Geometry of the survey point
	Transformation	Varchar2 (250)	Documenting between survey point and map point
	mapPoint - clustering - R-tree index	Mdsys.sdo_geometry	Geometry of the map point
	type (FK) - ref LA_PointType (cID)	Varchar2 (5)	Type of the point
	beginDateTime (PK2)	Date	Begin lifespan version
	endDateTime - constraints	Date	End lifespan version (EndDate > BeginDate)
MY_PointView - create view select *,	X	Dec (7,3)	X value of the point
	Y	Dec (7,3)	Y value of the point
	Z	Dec (7,3)	Z value of the point
MY_Boundary-FaceStringPoint Relationship	bfsID (PK1, FK) - ref MY_BoundaryFaceString (bfsID) - clustering 1	Varchar2 (10)	ID's of the baundary face string = *edge*
	pID (PK2, FK) - ref MY_Point (pID) - clustering 2	Varchar2 (10)	ID's of the point
	sequenceNr	Number (10)	Sequence number of the point
	beginDateTime	Date	Begin lifespan version
	endDateTime - constraints	Date	End lifespan version (EndDate > BeginDate)
MY_ParcelUnit	suID (PK1) - B-tree index	Varchar2 (73)	ID's of the parcel unit

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	sID (FK) - ref MY_SpatialSource (sID)	Varchar2 (25)	ID's of the spatial source
	lID (FK) - ref MY_Level (lID) - constraints	Varchar2 (25)	ID's of the level (MY_Level.name = 'level 4')
	dimension (FK) - ref LA_DimensionType (cID)	Varchar2 (5)	Dimension of the parcel unit
	type (FK) - ref MY_ParcelUnitType Type (cID)	Varchar2 (5)	Type of the parcel unit
	area_m^2	Dec (7,3)	Area of the parcel unit
	volume_m^3	Dec (10,3)	Volume of the parcel unit
	geometry - constraints - clustering - R-tree index	Mdsys.sdo_geometry	Geometry of parcel unit (Oracle gtype = 3007, 3D multipolygon)
	beginDateTime (PK2)	Date	Begin lifespan version
	endDateTime - constraints	Date	End lifespan version (EndDate > BeginDate)
MY_LotType	cID (PK1) - clustering	Varchar2 (5)	ID's of the code
	description	Varchar2 (50)	Description of the code
	beginDateTime (PK2)	Date	Begin lifespan version
	endDateTime - constraints	Date	End lifespan version (EndDate > BeginDate)

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Nur Amalina Zulkifli is a researcher at the Department of Geoinformation, Faculty of Geoinformation and Real Estate, Universiti Teknologi Malaysia (UTM), Skudai, Johor in Malaysia. She received a degree in Surveying Science and Geomatics from Universiti Teknologi MARA (UITM) in 2008. She is currently working on her MSc research concerning Land Administration Domain Model (LADM) for 2D and 3D cadastral registration.

Alias Abdul Rahman is a professor at the Department of Geoinformation, Faculty of Geoinformation and Real Estate, Universiti Teknologi Malaysia (UTM), Skudai, Johor in Malaysia. He received a degree in Surveying and Mapping Sciences from North East London Polytechnic, England, UK in 1987, Postgrad Diploma in GIS from ITC, Netherlands, and MSc in GIS also from ITC, Netherlands. In 2000 he received his PhD degree from University of Glasgow, Scotland, U.K. He currently leads the 3D GIS research group in the faculty.

Hasan Jamil is Deputy Director General II, Department of Survey and Mapping Malaysia since 2010 and have been with the Department of Survey and Mapping Malaysia in various capacities since 1979.

Teng Chee Hua obtained a degree in Land Surveying in 1980 from University of Technology, Malaysia (UTM). In 1982 he received a Post-Grad Dip in Photogrammetry from ITC, The Netherlands, in 1992 received a MSc from University of New Brunswick, Canada, and a PhD from University of Newcastle, United Kingdom in 2000 for his thesis 'Object recognition assisted by GIS using expert system and ANN'. Since 1980, he has been working with the Department of Surveying and Mapping, Malaysia and involved with various projects carried out by the Department such as GDM2000, core RTKnet, precise geoid, coordinated cadastre system and eKadaster. Currently, he is the Divisional Director for Cadastre.

Sr Dr. Tan Liat Choonis currently the Assistant Director of Survey attached to the Department of Survey and Mapping Malaysia (JUPEM). Previously, he was the Assistant Director with Malaysian Centre for Geospatial Data Infrastructure (MaCGDI). He received his Certificated in Land Survey (1993) from Politeknik Kuching Sarawak, Malaysia, in 1993, Diploma in Land Survey from University Teknologi Malaysia (UTM), in 1996, Degree in Land Survey from UTM, in 1998, Master in Land Administration and Development from UTM, in 2002. In 2013, he received his PhD from UTM for his thesis on "Towards Developing a Three-dimensional Cadastre for Three-dimensional Property Rights in Malaysia". His research interests focus on 3D property legislation and Land Registration System.

Sr Looi Kam Seng is currently the Principle Assistant Director of Survey attached to Department Survey and Mapping Malaysia (JUPEM). He first attach as Assistant Director with Department of Survey and Mapping, Penang. He received his Degree in Land Survey from UTM, in 1991. He is also a registered land surveyor since 2011.
Chan Keat Lim graduated from the University of Nottingham with a Master of Science in

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Geographical Information Systems (Distinction) and University Teknologi Malaysia with a Bachelor of Science in Land Surveying. Currently, after being various other positions during the last 25 years, he is the Director of Survey (Cadastral Legislation) in the Cadastral Division, Department of Survey and Mapping Malaysia (JUPEM). He was a member of the Strata Titles Act (Amendment) Drafting Committee and also assisted in the drafting of the Strata Management Act 2013.

Peter van Oosterom obtained an MSc in Technical Computer Science in 1985 from Delft University of Technology, The Netherlands. In 1990 he received a PhD from Leiden University. From 1985 until 1995 he worked at the TNO-FEL laboratory in The Hague. From 1995 until 2000 he was senior information manager at the Dutch Cadastre, where he was involved in the renewal of the Cadastral (Geographic) database. Since 2000, he is professor at the Delft University of Technology (OTB institute) and head of the section 'GIS Technology'.He is the current chair of the FIG working group on '3D-Cadastres'.

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