

Embedding 3D into Multipurpose Cadastre

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SUMMARY

There is no doubt that the cadastral map provides a useful entrance to information in a land parcel based information system. However, such information system could be made more meaningful and useful if it can be extended for multiple usages with multi data layers, and in three-dimensions (3D). Currently, many national mapping and cadastral agencies (NMCAs) and users deal with complex situations, and we believe that 3D could enhance the understanding of the situations better. This paper describes the new initiative of Malaysian NMCA towards developing a multipurpose cadastre (MPC) based on large scale spatial data layers grouped into two types of sub systems. The first group consists of components with spatial objects to which legal and administrative facts are attached (rights, restrictions and responsibilities), such as 3D cadastre (volume parcels), 3D marine cadastre, and 3D strata (in buildings). The second group consists of components with reference spatial objects, such as: 3D topography (with buildings footprints), underground utility (3D), and 3D city model (with roof structure and LoD3 buildings). The current status of each of these components will be discussed in this paper. The paper highlights the scope of the Malaysian MPC, the requirements with respect to current cadastre and mapping databases. Recommendations and outlook for future tasks and development for realizing the MPC will be discussed as part of the conclusion section of the paper.

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1 INTRODUCTION

Cadastre is the term used to describe the process of acquisition and ultimate ownership of a land parcel on the surface of the earth within a regional boundary such as a country. Dale and McLaughlin (1988) described land as the primary resource for wealth creation. The economic and social well-being of a populace depends on the activities being taking on land. Land here refers to both land surface and sea surface; this can be above, on and below these surfaces. Property or land administration for any country needs to be effective and secured, hence countries all over the world require accurate demarcation of land parcels to determine location and extent of land parcels, establish accurate land ownership and ensure the proper documentation of land related data. Subsequent documentation of a cadastre is guaranteed to serve as security to land ownership thus serving as a vehicle for social and economic change. The cadastre also serves as the supporting tool for land policies, fiscal policies and agricultural policies. Current European multipurpose cadastral systems are intended for either taxation or for title registration for planning purposes. Common denominators in these types of cadastre are the unambiguous identification of spatial property and a standardised numbering scheme that is uniformly referenced. This identification method allows different vertical application areas, such as taxation, legal, and planning offices, to refer to the same real property. Thus, when the fiscal cadastre promulgates a change on the tax record of a specific parcel, a map from the cadastre system shows the tax information changes on the same parcel for the legal cadastre.

The cadastral system in Malaysia is a parcel based systems and can be considered as 2D system that provides land and property information such as basic ownerships of the parcels. Current information and GIS technologies able to provide better information as more and more cadastre system users were engaging with complex real world situations especially in big cities and also for advanced applications. In other words existing cadastre system needs to be extended for those advanced information and applications requirements. There are a number of countries (or rather groups of researchers) attempt to develop 3D cadastre such as Netherlands, Australia, Norway, Sweden and Israel (Stoter, 2004). The development of the 3D cadastre is getting better today as compared to early 2000 where it has been actively worked out and monitored by the joint FIG Commissions 3 and 7 working group 3D-Cadastres.

Recent developments in cadastre as well as in other mapping and GIS show that a new system that works for various users and applications is inevitable, i.e. Multipurpose Cadastre (MPC). Although this system was proposed as early as 1970s, there are still many issues and impediments for such system to be realized. The national mapping organization in Malaysia,

the Department of Survey and Mapping Malaysia (DSMM) plans to implement the MPC for some parts of the country. In general MPC has been recognized in the past as a cadastre system that deals with multiple usages or applications from the cadastre information, e.g. application for banks and also for other agencies. Today, cadastre system could be extended and developed from various subsystems and data sources e.g. from 3D cadastre, marine cadastre, 3D topographic data, 3D city models, etc. It is the aim of the DSMM to develop such system. Our definition of MPC can be summarized as follows “. . . it is a system that utilizes major cadastral and other large scale spatial data such as cadastral lots with heights, building footprints, 3D building including stratum (parts of buildings that exist below the surface), underground utility objects (such as pipes and cables), and 3D city models”. The following Figure 1 illustrates the general view and the components of the proposed MPC. Descriptions of current status of 3D cadastre and the registration of objects are described in Section 2. The components of 3D for MPC are discussed in Section 3, and finally the conclusion of the paper in Section 4.

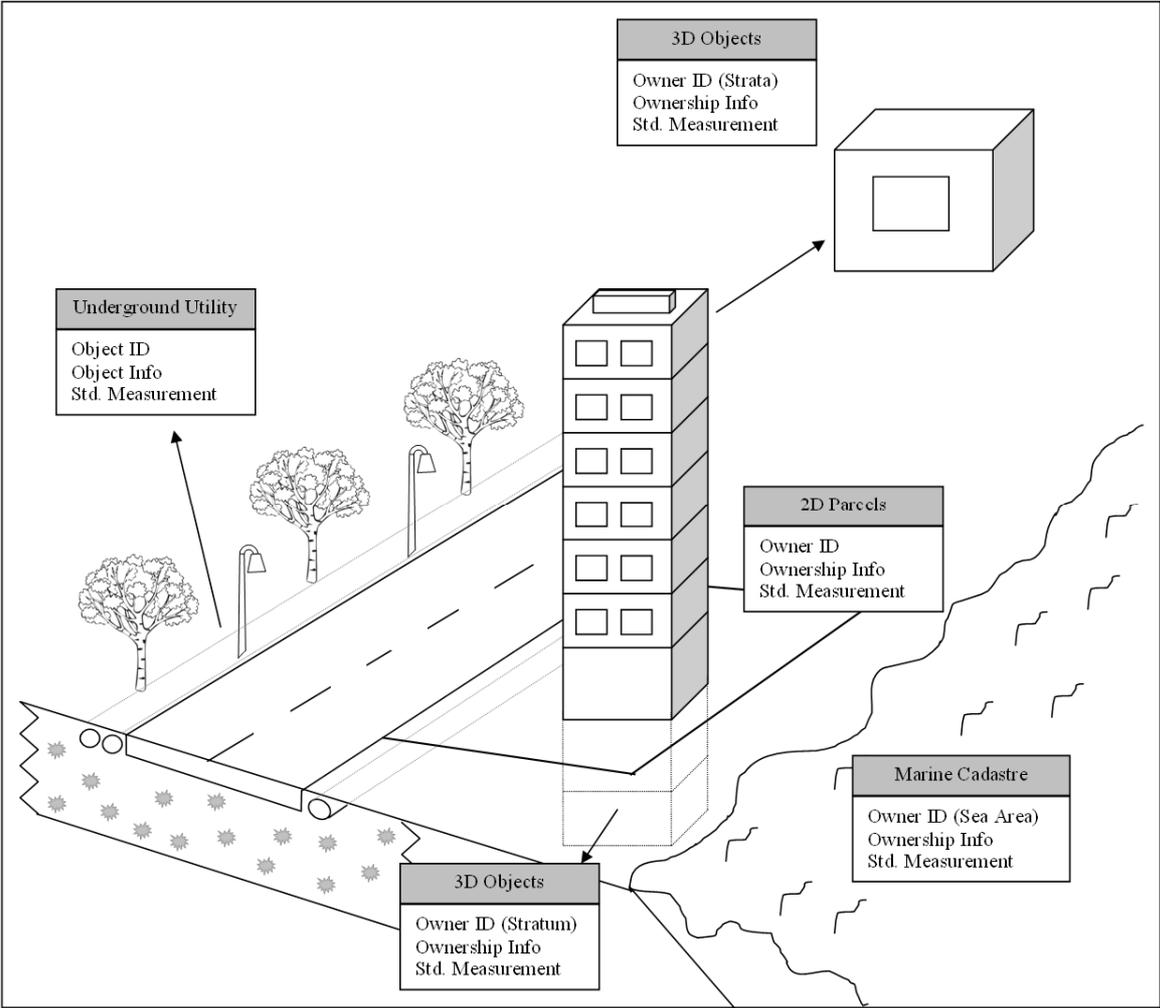


Figure 1: The anticipated schematic diagram of MPC

2 3D COMPONENTS OF THE MPC

This section describes the components that could be integrated into the MPC.

2.1 3D Cadastre

We anticipate, 3D cadastre should be included in the MPC since the full operational 3D system can provide many useful information for the 3D property situations. The component could be extended from the existing DSMM's strata system where basic information ownerships of units within high rise buildings are in place. Currently, the wireframe and CityGML LoD1-looks buildings visualization capability can be easily upgraded into more realistic view as supported within 3D city model. However, the current strata system is still not able to answer many "3D" questions as proposed by Stoter (2004) and other researchers such as Thompson and Oosterom (2010), and Hassan and Abdul Rahman (2010). The following Figure 2, Figure 3, and Figure 4 show some of the related works of the latter for the Malaysian 3D environment.



Figure 2: Example of the 3D situation.

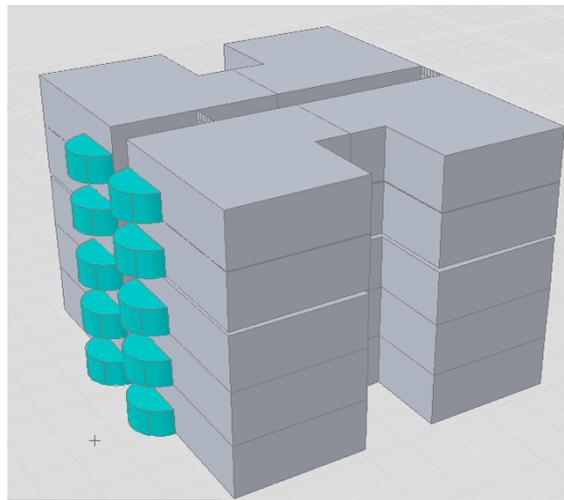


Figure 3: Visualization of 3DParcel in CAD.

Query for the administrative purposes can be done via the developed interface by creating a linkage to a database such as Oracle. Figure 4 shows example of the query and it is based on "Owner_ID" and other attributes of the registered objects.

Cadastre system is being used by some government agencies such as Local Authority and Inland Revenue Board of Malaysia (LHDNM) to support the valuation and taxes system. In Malaysia, here are two organizations responsible on managing and maintaining the cadastre system (Genggatharan 2005). The Department of Survey and Mapping Malaysia (DSMM) deals with the cadastral survey with high accuracy survey determine the location, dimension and size of the properties. The Cadastral Survey System of DSMM is responsible for preparing, producing and managing the spatial component including the surveying and mapping of the cadastre parcels. The Land Registration System, which is non-spatial data is being the responsibility of the Land Office (i.e. also known as *PTG*). The PTG deals with the

ownership registration, i.e. who owns what (Right, Responsible, Restriction), the RRRs. Both organizations have their own systems called CLRS (Computerised Land Registration System) in PTG and CDMS (Cadastre Data Management System) in DSMM. Unfortunately the systems are not integrated and still in 2D in nature (Chong, 2006). As far as these agencies are concerned the needs for a real 3D cadastre system is evident.

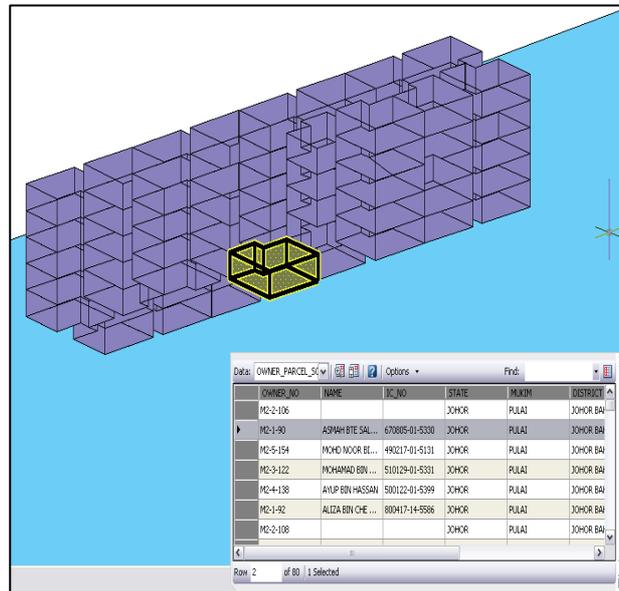


Figure 4: Query with the attribute information

The legal aspect

The basic concept of land parcel (lot) in Malaysian land law is the infinite ownership space defined as a cone down to the centre of earth, with boundaries on the surface extends vertically upwards and downwards to an extent. Its adjudication consists of two parts, first the ascertaining of the physically surface boundaries by surveyed boundary marks, then the official ascertainment of rights in land via registration and issue of documents of title. However, it should be noted that existing Malaysian cadastre deals with properties located not only on the surface, but also above and below the surface level. For all intents and purposes, the rights and responsibilities of the proprietor of the surface parcel shall also apply to the proprietor of the underground land. There are also provisions to survey and issue title for strata and stratum. Such a 3D parcel is defined by the bounding floor, walls and ceiling. Individual parcels are then issued with strata title in accordance to a strata registration. On the other hand, the cadastral map or Digital Cadastral Database (DCDB) is only two-dimensional in nature. It contains neither altimetry information nor detailed information of existing objects or structures within the parcel area. The vertical dimensions are only available on the strata and stratum certified plans, as scanned images in the image library.

The organizational aspect

The cadastral system comprises a land registration system and a cadastral registration as key components. Land registration is a state government responsibility while cadastral registration is under federal government responsibility. According to Chong (2006), experiences in

developed countries have shown that stand-alone or isolated approaches where data and processes were maintained separately are not sustainable. A non-unified land registry system is known to have the following shortcomings¹:

- Legal administrative and cadastral mapping data integrity is not well maintained.
- Work flow, data updating and data service are less efficient (incomplete DCDB and patches of irregularities of CLRS and DCDB)
- Quality and consistency of information are difficult to maintain due to parallel registration and updating
- Less cost effective (examples include overheads to deal with two separate government departments for one land related transaction – one might be located at the state capital but the other at district, or extra efforts to ensure data integrity during data exchange as both set of records are inter-dependant)

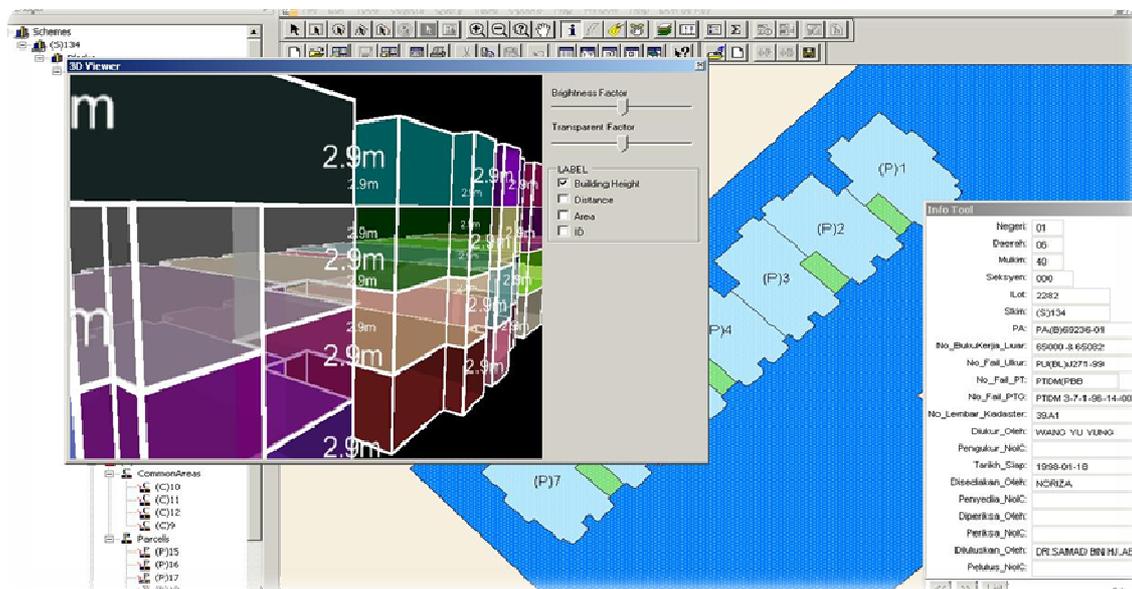


Figure 5: Query from 3D strata system

2.2 3D City Models

Buildings and other important objects within a city and other urban areas could be managed via 3D city model (3DCM) functions and applications. Information related to these objects could be easily retrieved with respect to five level-of-details (LoDs), i.e. CityGML LoD0, LoD1, LoD2, LoD3, and LoD4. 3DCM as one of the MPC components provides information such as “what is the total area of the windows of a building”, etc. Other queries such as how many buildings, monuments, trees?; How many stories?; Total sealed area?; From which windows can I see place XY?; What is the total window area of the buildings?; Where are the entrances / exits?; What is the energy demand for heating and electricity? The spatial database of 3DCM as shown in the following figure is able to answer those queries.

¹ These shortcomings may be (partially) resolved with the developing Spatial Information Infrastructure, which allows more distributed work flows. Of course, organizational agreements must be made for this.

The 3DCM does describe physical object (and not legal objects), which are important for reference purposes (and make 3D parcels meaningful). Construction of 3DCM from various data sources has been described by several authors including Alizadehashrafi et al 2010, Kolbe 2010, Coors 2010, Buyuksalih 2010 and others. However, literature suggests that not many works were reported on 3DCM with MPC and thus, it is a worthwhile to investigate those two.



Figure 6: 3D city model of Putrajaya, Malaysia

2.2 3D Underground Utility

It is one of the important data layers in MPC as it could provide information on underground objects such as cables (power and telecommunication), pipelines, etc. Currently, most of the underground database efforts by various groups were not integrated with cadaster database and other databases as exist in many places and cities in many countries. It is desirable for NMA to establish such a system so that more and more information could be generated. Utility networks are usually represented as lines (segments of the networks) and points (connections, valves, etc.) predominantly with their X,Y coordinates. Depending on the type of the utility networks (water, sewerage, telecom, etc.), the depth or (more rarely) the Z coordinates (in given points) might be registered. The software (GIS, CAD, AM/FM) for utility maintenance is typically 2D, i.e. the visualization of all the elements of the networks is on 2D maps. Various factors contribute to confusion and misinterpretation of the information on 2D maps. Firstly, the major trace of pipelines or cables per network is mostly the same, i.e. under the streets, which results in overlapping lines on the map. To avoid this overlap, many companies offset the multiple pipelines to increase the readability of the map. Such an approach, however, could mislead unfamiliar users. Secondly, the trace of the different utility networks also overlaps. Color and depth (depicted near a segment) of a particular pipe or cable are often the only parameters to distinguish between different networks. Integrating several networks on one map is almost an impossible task. Thirdly, a large number of important elements of the networks (such as valves, connections) are given with symbols, which might be challenging for interpretation from non-specialist and even from some of the less-qualified field workers. Finally, some of the networks (e.g. sewerage) contain a large amount of vertical elements, which visualization on the 2D maps is only as points. Explanations about the vertical elements is often not included in the maps relying on the on-site experience of field workers

The drawbacks of 2D visualization of utilities are not new. However, the rapidly increased utilization of underground space by utility companies requires more extended knowledge about the position of underground utility networks that ever before. The intensive expansion

and modernization of cities (involving re-construction of streets, buildings, etc.) needs reliable information about existing infrastructures. Recent investigations (Roberts et al 2002) have revealed an increased number of accidents of various ranges and scales. It is clear to many governments that a 'centralized management' of utilities is the only way to improve the knowledge on the underground infrastructure (Chong 2006, Hei et al 2002, Penninga and Oosterom 2006).

3D database and visualization of utilities is considered by many such as Du (2005) and Chong (2006) as able to solve many of the drawbacks mentioned above. 3D visualization of pipelines is necessary tendency for development of urban pipe and cable systems, because it can clearly express the position and spatial relationship of all pipelines. Arbitrary displays of pipe-lines from any view and/or from any a place (also for profiles) can be created. In such a way, blind-cutting and fault damaging of pipelines can be considerably avoided. Particularly, in the case of crisis recovery after unexpected accidents or natural disasters, e.g. emergent fires, gas-leakage, anti-terrorism, flooding and earthquake, 3D visualization may provide vivid graphics in such a crisis epoch for a quick decision-making, in order to save precious time and to avoid life and economical loss as soon as possible. Research is emerging aiming at improved utility visualization. Roberts et al. (2002) suggest an augmented reality system for 3D visualization of utilities (showing their position on the surface with attached depth information). Peng et al 2002 discuss profile creation from a utility model to maintain the pipes and the lines with their 3D coordinates. He et. al. (2002) presented a formal approach for underground utility system.

In Malaysia, maintaining underground utility mapping information is an important task for development, maintenance, and upgrading of underground utility infrastructure. Taking into account the increasing instance catastrophic damages of underground utilities and disruption of existing utility services resulting from excavation works, the cabinet of Malaysian Parliament, in its meeting on 24th August 2004 has decided that the Department Survey and Mapping, Malaysia (DSMM), shall undertake the responsibility of maintaining of repository of all underground utility data, apart from those kept by the various utility agencies. (i.e. *Syarikat Telekom Malaysia Bhd, Indah Water Konsortium Berhad, Tenaga Nasional Berhad (TNB), Gas Malaysia Sdn Bhd*, etc.). The data collected will then be provided to relevant parties involved in new underground utilities project to minimize the risk associated with construction activities that may affect existing underground utilities. In order to undertake this new responsibility, DSMM expected to embark on the creation and subsequently, the maintenance of National Underground Utility Database. The data are in 2D and the attribute will maintained in the DBMS. The underground utility database is at early stage and 3D database is one of the NMA's plans. Recently, an initial research has been made by Universiti Teknologi Malaysia (UTM) to develop a 3D spatial database for utility objects such as pipes and cables and attempt to incorporate with the MPC is underway.

3 POSSIBLE IMPLEMENTATION OF MPC BASED ON 3D CADASTRE

3D MPC could be implemented by using 3D cadastre as a base. Since the 3D cadastre in Malaysia is not yet in place, thus the option for such development is widely open. Initial work has been proposed by Hassan and Abdul Rahman (2010) on the possible implementation of the 3D cadastre for Malaysian situation. Many 3D situations or cases are yet to be defined by the relevant authorities. However, the authorities may follow model(s) as the ISO TC211 the Land Administration Domain Model (LADM), submitted by FIG to ISO. These models have been used as a platform to suit with the Malaysian cadastre system. This approach means preservation of 2D cadastre and the integration of the registration of the situation in 3D by registering 3D situations integrated and being part of the 2D cadastral geographical data set.

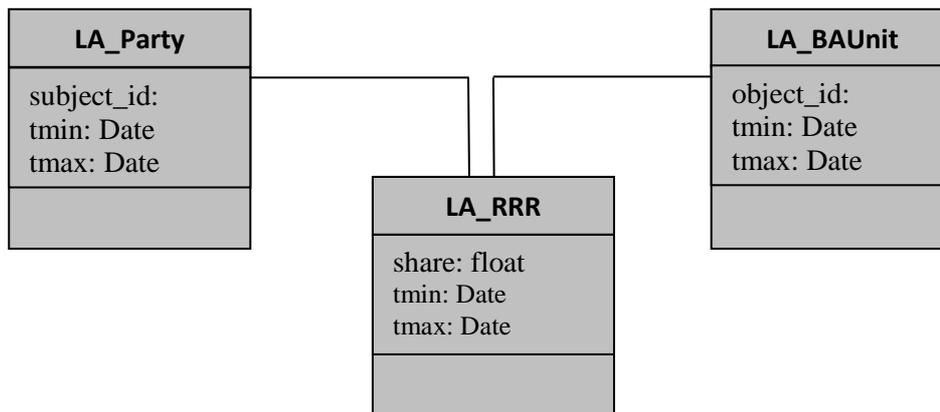


Figure 7: UML class diagram concept of LADM: LA_Party, LA_RRR (Right, Restriction, and Responsibility) and LA_BAUnit (stands for Basic Administration Unit),

Land Administration Domain Model (LADM) has been introduced as a model for land registration purposes. The development of this model is designed as a base for various land registration practice in different countries. Two important goals of this model as listed in (van Oosterom et. al 2006) are; (1) avoid reinventing and re-implementing the same functionality over and over again, but provide an extensible basis for efficient and effective cadastral system development based on a model driven architecture (MDA), and (2) enable involved parties, both within one country and between different countries, to communicate based on the shared ontology implied by the model. The UML class diagram of the LADM is shown in Figure 7.

LADM is designed as the base for various land registration system and could be used to describe Malaysian cadastre data model. The definition of these three core classes can be derived from (Chong 2006). Table 1 shows the component of LADM that follows with the Malaysia Cadastre System. These categories are base from the LADM classes and reflected in the National Land Code 1965 and Strata Title Act 1985.

Table 1: Component of LADM based on Malaysian Cadastre System

LA_Party (NLC: s.43)	Natural persons (excluding minors less than 18 years old) Corporations, sovereigns, governments or organisations Persons authorised to hold land under the Diplomatic and Consular Privileges Ordinance 1957 Bodies expressly empowered to hold land (e.g. Trade union Ordinance 1957)
LA_BAUnit, LA_SpatialUnit	Lot (land parcel) (NLC: s.516) Parcel (building parcel) (STA: s.4) Stratum (underground volume) (NLC: s.92A)
LA_RRR	Rights (e.g. extent of general disposal under NLC: s.44) Responsibilities (duty rent – e.g. survey fees, premium, annual quit rent etc.) Restrictions (e.g. category of land, express and implied condition etc.)

Integrated 2D and 3D parcels in hybrid cadastre, as proposed by Stoter (2004), can be used for the implementation of 3D cadastre in Malaysia. The concept of hybrid cadastre is to preserve the current 2D registration and add the 3D component in the registration system. There are two approaches to register 3D object namely registration of right-volume and registration of 3D physical object. However, the 3D representation of each approach is embedded in the LADM base model. An integrated 3D cadastre model looks on how to add 3D component in the current cadastre data model and make information interoperable between the two involved organizations. 3D cadastre objects, e.g. apartment buildings are real property that being built on the 2D land parcel, which is the responsibility of DSMM. Adapting LADM, the 3D spatial database being design to make it interoperable with the current land registration database developed by the LO, which is CLRS.

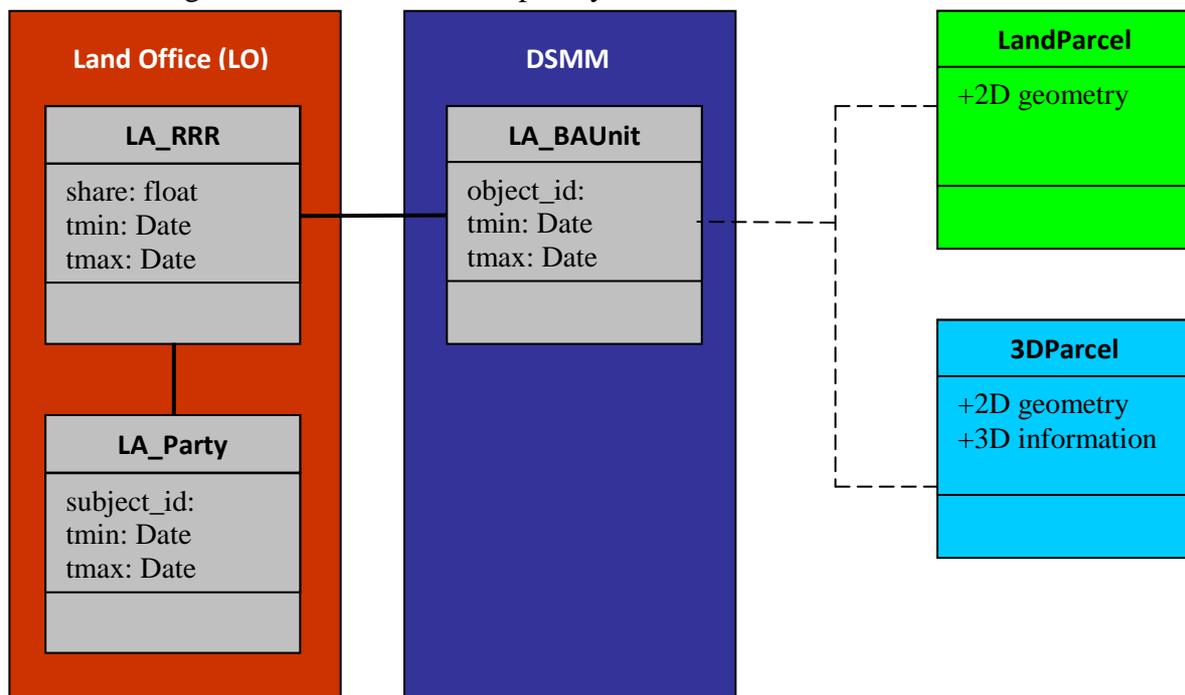


Figure 8: Adaptation of LADM into Integrated 3D Cadastre Model for Malaysia where LandParcel and 3DParcel (both specializations LA_SpatialUnit) are part of LA_BAUnit

DCDB and CLRS could be integrated electronically via the Spatial Information Infrastructure (SII). Furthermore the integration of the spatial database of DCDB with the textual database of CLRS is the prerequisite requirement for the formation of a comprehensive land information system. Initial research was conducted by Genggatharan (2005) proposed a mechanism to integrate these two databases. Nevertheless, there are many hurdles to cross at current stage of practice. Genggatharan (2005) underlines the following issues associated with the proposed integration:

- Technological – compatibility of existing hardware and software
- Data - data quality and integrity
- Organizational - there is no mechanism for exchanging data among organization
- Legal - data custodian and rights
- Different working procedures and practice

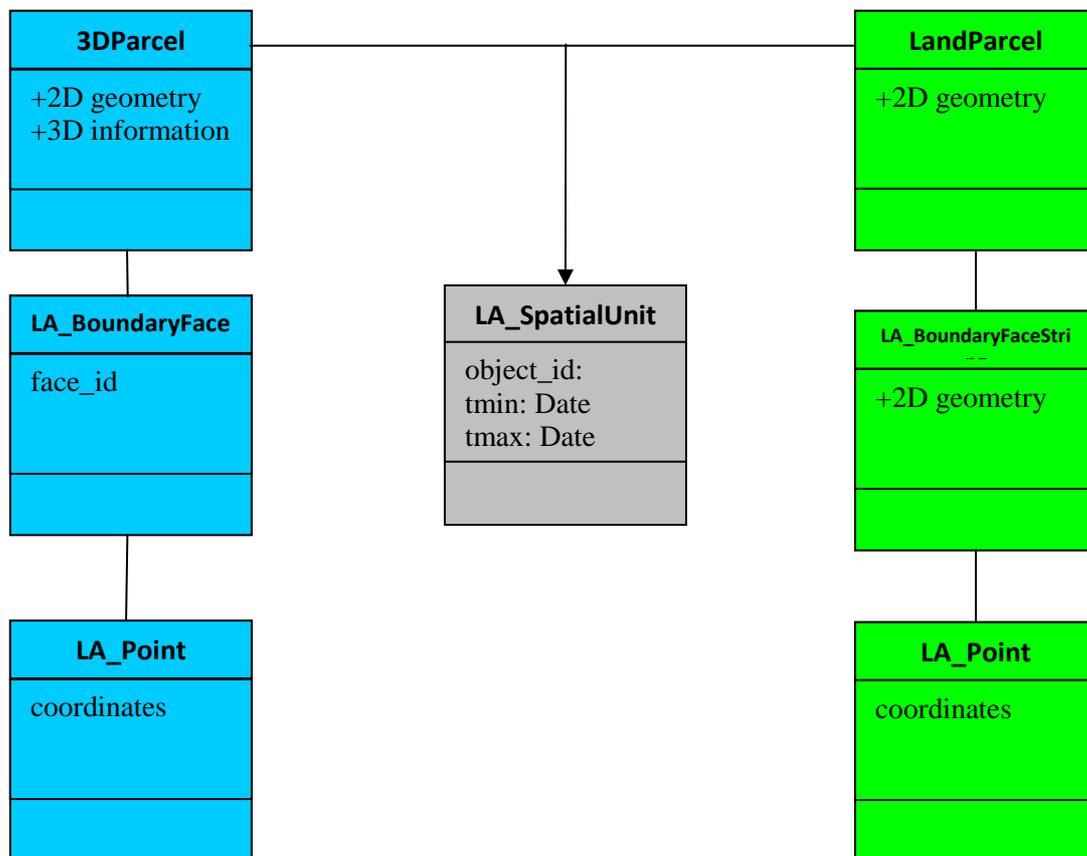


Figure 9: The data model of LandParcel and 3DParcel as LA_SpatialUnits.

From the issues as listed above (bullets), technological and the data aspect will be the major concern of having the integration 3D cadastre. The organizational aspect, legal aspect and also different working procedures and practice will be discussed. Adaptation of LADM into integrated 3D cadastre model for Malaysia as illustrated in Figure 8. It is clearly defined that the owner (represent a *LA_Party* in the diagram) and the *LA_RRR* (Right, Restriction,

Responsibility) are under responsibility of the LO while the properties or basic administration units (*LA_BAUnit*) are under responsibility of DSMM. The integration between these two databases is made on the linkage of *LA_BAUnit* and the *LA_RRR* in the Integrated 3D Cadastre Model for Malaysia. In this model, both *LandParcel* and *3DParcel* are registered as an object in current registration system.

The *LandParcel* is represented as a 2D geometry. This object is inherited from the current 2D registration system. Figure 9 shows the data model of land parcel as a registered object. *LandParcel* i.e. cadastral lot consists of boundary lines and boundary marks. *3DParcel* is formed with 2D geometry and 3D information. The *3DParcel* is projected with the 3D bounded space with list of coordinate that form flat faces and later form a 3D object which so called 3D cadastre object.

The spatial data model of *LandParcel* and *3DParcel* are stored in the Oracle DBMS. The table recording 3DParcel include the following items:

- 3DUnit_no: the ownership number of the particular building
- Area: the floor area of the building parcel
- Geometry: the list of coordinates which form the 3D spatial objects

The table recording the *LandParcel* includes the following items:

- No_lot: Lot number of the mother parcel for buildings registered
- Area: the area of the main parcel for the buildings
- Geometry: List of coordinates that form the 2D Parcel

The administrative component is created to show the attributes for registered 3D cadastre object. The attributes shows the information as in Table 2.

Table 2: Physical Development of 3D Cadastre Registration Database

Entity Name	Geometry Type	Field Name	Description	Data Type	Width	Key
BAUnitRRR		BAUnit_No	Basic Admin Unit no.	Varchar	25	PK
		Name	Name of land propprter	Varchar	25	
		IC_No	IC no.	Varchar	15	FK
		State	Name of state	Varchar	10	
		Mukim	Name of mukim	Varchar	10	
		District	Name of District	Varchar	10	
		Type_owner	Type of ownership	Varchar	10	
3DParcel	Polygon	3DUnit_No	3D spatial unit no.	Varchar	25	PK
		Area	Area of parcel	Number	10	

		Geometry	Column of geometry	Mdsys.sdo.geometry		
		LotNo.	Lot Number	Varchar	10	FK
		BAUnit_No	Basic Admin Unit no.	Varchar	25	FK
LandParcel	Polygon	LotNo.	Lot No	Varchar	10	PK
		Area	Area of parcel	Number	10	
		Geometry	Column of geometry	Mdsys.sdo.geometry		
		BAUnit_No	Basic Admin Unit no.	Varchar	25	FK

The table recording table BAUnitRRR (combined LA_BAUnit and LA_RRR tables) include with the following items:

- BAUnit_No. : the basic admin unit number of particular registered object
- Name : link via name of person who hold rights on the registered parcel
- IC_No. : link via identification number of the land owner.
- State : description name of the state for the basic admin units
- Mukim : the name of the mukim of the basic admin units
- District : the name of district of the basic admin units
- Type_owner : type of ownership referring to basic admin units



Figure 10: Sample building for the experiment.

Table 2 shows the physical development of the registration for 3D cadastre object. There are three main entities that are BAUnitRRR (covering both LA_Unit and LA_RRR), 3DParcel and LandParcel. The 3D cadastre registration system is developed to show registration of 3D spatial objects and combine with the land attributes. The linkage of these tables is based on BAUnit_No (field name) that being set as primary key (PK). The 3D Parcel is located in the primary land of 2D parcel. Therefore, the linkage between these tables is based on the lot no. The sample data of building as shown in Figure 10 has been chosen for the experimental purposes. In the experiment, we have chosen Autodesk Map 3D and Oracle database to visualize the spatial objects. The interoperability of Map 3D and Oracle is developed based on the schema that helps to connect the software. The specification of the schema need to be fulfilled before the connection can be done.

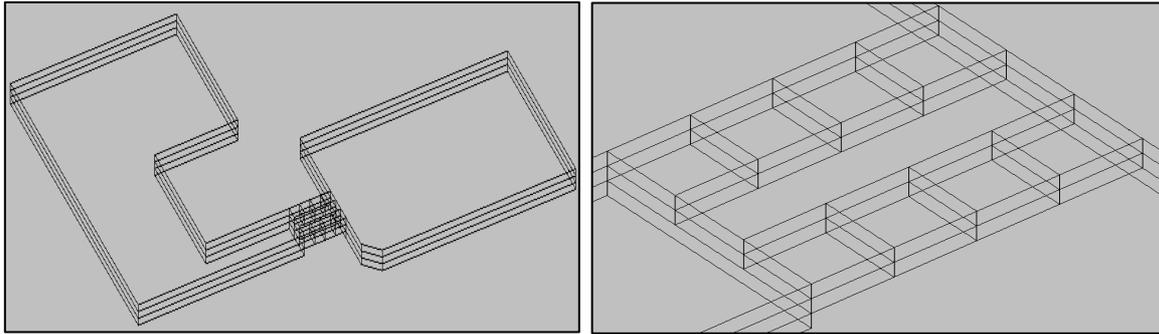


Figure 11: Visualization of 3DParcel in CAD

The visualization of 3D cadastre object is conducted via the Map 3D schema administration. Here, the Map 3D requires user to login the Oracle database login name, password and the service name. Later, the interested table in the Oracle database will be selected to visualize in the Map 3D. The visualization of the 3D cadastre objects are shown in Figure 11. The registered coordinates in the Oracle DBMS can be listed base on the primary key of the table.

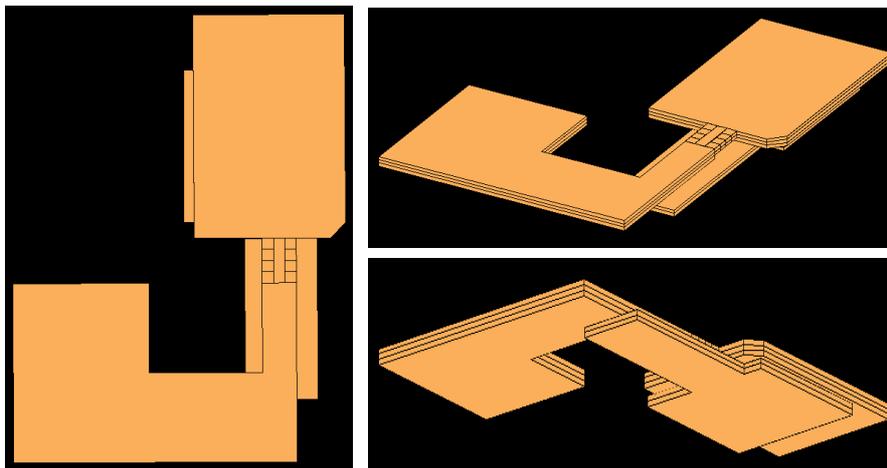


Figure 12: 3D model extracted from Oracle Spatial

The developed 3D spatial database in oracle spatial software can be viewed using different software; however in this paper we used Autodesk Map 3D 2007 as viewing tools. As a result, the CAD drawing which are in the drawing (dwg) format have been translate into Oracle Spatial database and Figure 12 show the 3D spatial model which are extracted from the Oracle spatial database and viewed in Autodesk Map 3D. Finally, the linkage between the spatial and the attribute information of the 3D model (see Figure 13) allow us to do some simple queries for the administrative purposes.

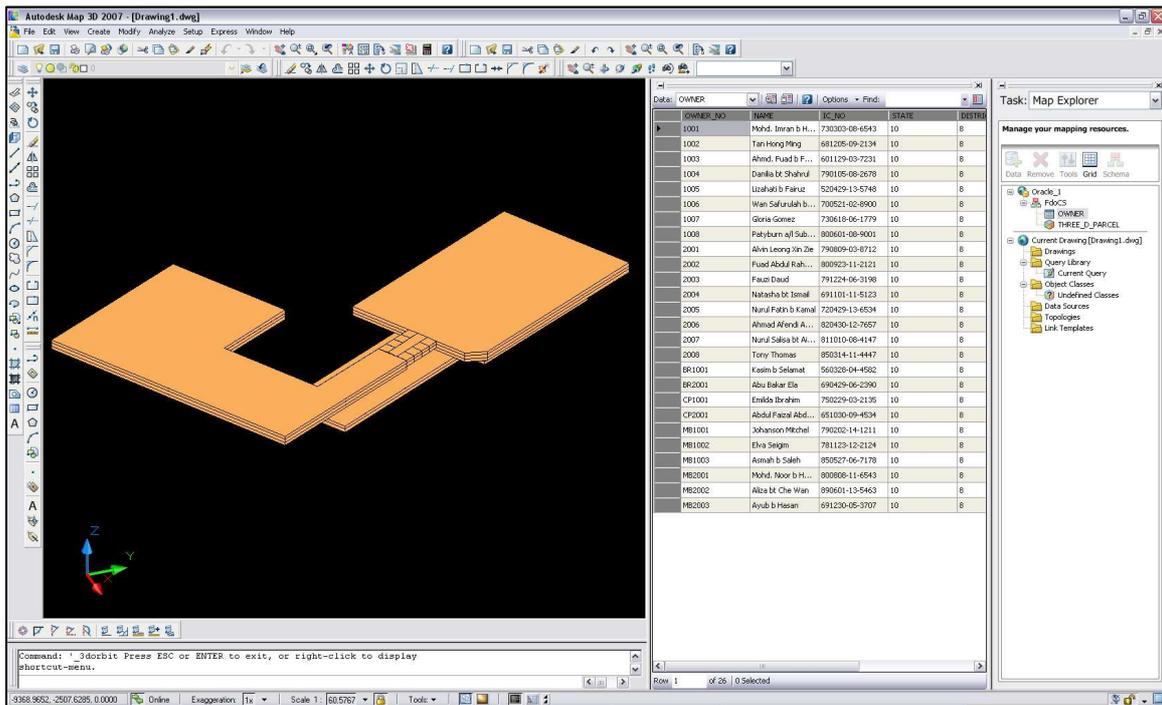


Figure 13: 3D database developed for Malaysian 3D Cadastre purposes.

4 CONCLUSIONS

This paper has described a possibility of embedding 3D into newly initiated MPC project for the Department of Survey and Mapping Malaysia (DSMM) from the components such as 3D cadastre, 3D strata, 3D city model, 3D utility objects, and 3D topography. The foundation of the proposal is the LADM of the ISO TC211, which offers integrated support of 2D and 3D parcels. A Malaysian LADM profile has been developed for this purpose. Initial test have successfully been conducted by loading 3D test object in an Oracle spatial database and accessing this with Autodesk Map 3D. We believe that those non-integrated components or systems could be synergized for next generation of 3D MPC.

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