# An LADM-based Approach for Developing and Implementing a National 3D Cadastre – A Case Study of Malaysia

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## SUMMARY

With the growing dominance of multi-storey buildings and other infrastructures, 2D-based cadastral systems are facing new challenges in recording, managing and visualising the spatial extent of vertically stratified cadastral spaces. In Malaysia, surveying and cadastral measurements are currently stored in the National Digital Cadastral Data Base (NDCDB), which is a 2D-based database in the form of planimetric coordinates (X, Y). However, in reality, cadastral objects are three dimensional and 2D-based approaches provide a fragmented view of these 3D spatial objects. Another challenge is that multiple pages of 2D drawings, which are used to show all the spaces of multi-storey buildings and surroundings, imposes a significant amount of cognitive effort for inexpert stakeholders who cannot easily understand the accurate location of cadastral boundaries obscured within physical structures. Therefore, the methods of data collection, calculation and adjustment of existing survey and processing data needs to be upgraded for the purposes of implementing 3D cadastral database and producing 3D digital certified plans.

The international land administration domain model (LADM) standard provides a formal conceptual model for recording and managing land administration data. It provides an extensible basis for the development and refinement of efficient and effective land administration systems, based on a Model Driven Architecture (MDA), and enables involved parties, both within one country and between different countries, to communicate, based on the shared vocabulary (that is, an ontology), implied by the model. The latter is required for the sharing and exchange of data.

There have been several research and development activities in the past to model 3D cadastre in Malaysia. However, these investigations mainly remain at the theoretical level and yet to be implemented in the real context of Malaysian jurisdiction. Therefore, the motivation for this paper is to discuss the current initiative of Malaysian government to discuss the practical pathway towards realising an LADM-based 3D cadastral system in alignment with jurisdictional settings of Malaysia. It focuses on data migration from existing database to open source data base and the application modules for implementation of 3D cadastral system and

3D cadastral database by using open source platform. In developing the prototype system, the project investigates how the current 2D NDCDB should be upgraded to 3D and how the current workflows and associated data to be modified to support the realization of the 3D cadastral system. In doing so, this paper aims to document the requirements of – Malaysian mapping agency –The Department of Survey and Mapping Malaysia (JUPEM) and its stakeholders for the process of upgrade. The methodology for the documentation includes reviewing JUPEM documents and workflow, review of online resources, visit to JUPEM and interview with experts in JUPEM.

The paper proposes strategies for the implementation of 3D-NCDB, which includes the processes for upgrading the existing dataset and data collection methods to support the 3D digital data and the creation of 3D spatial database based on the elicited user requirements. The adopted approach will support the integration of complementary modules, especially for 3D spatial data input, 3D adjustment and validation of 3D spatial data. The implementation of 3D-NDCBD is an initial step to develop 3D Kadaster System that includes the upgrade of the hardware, software and application modules to support 3D data. The major motivation of this upgrade is to introduce an open-source 3D database, which is LADM compliant, to address issues with regards to the existing eKadastre project in Malaysia.

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## 1. INTRODUCTION

Land administration domain model (LADM) offers a formal mechanism for describing land administration data. This can be implemented by developing an application schema or of the LADM model profile. Using Model Driven Architecture (MDA), it provides an extensible basis for the development and refinement of efficient and effective land administration systems, it also allows involved parties, both within one country and between different countries, to communicate, based on the shared vocabulary provided by the model. This provides a good platform for data sharing and exchange.

There have been several attempts by different national jurisdictions to adopt LADM. However, as it stands presently, these attempts have largely been at the conceptual stage. The current state of 3D cadastral registration in describing land administration data, in Malaysia, is being done using strata plans for above ground properties and stratum plans for underground properties.

One of the main reasons for initiating the adoption of LADM in Malaysia by JUPEM is that LADM is an international standard that has been developed and endorsed by the International Standardization Organisation (ISO). In addition, there is the realization that modern cadastral systems need to move away from the traditional concept of cadastre to a more integrated cadastral modelling. The anticipation that the adoption of LADM could contribute to a higher rating for Malaysia's land administration which could positively impact on the World Bank's ease of doing business rating for the country is also a major consideration. Getting a good rating has been given much emphasis by the Malaysian government to improve the business environment and lower costs apart from attracting foreign investments into the country.
The understanding that LADM covers land registration and cadastre in a broad sense, suggests that it could improve interoperability between cadastral or related information systems. This would consequently improve the exchange of land information not only between local and national, but international organizations as well.

In relation to the above, it is considered that LADM will facilitates appropriate system development; it will enable communication between different systems in different organizations whereby the application design can be based on GIS and database technology. In using standards, information can then be exchanged in heterogeneous (commercial and open source) and distributed environments. The implementation of LADM can be performed in a flexible way; the standard can be extended and adapted to local situations and ecosystems.

Despite all these, it is clear at this stage that there are some specific challenges that impedes conforming with the FIG recommendations of developing a comprehensive LADM that supports 2D and 3D cadastral registration in Malaysia. Among these are:

(i) Measurements and storage issues, which currently, are stored in the National Digital Cadastral Data Base (NDCDB) that is a 2D-based database (X, Y), in the form of 2-dimensions (X, Y) planimetric coordinates. In reality, cadastral objects are three dimensional and are, thus, required to be represented in 3D. It is therefore JUPEM's intention to investigate the capability of producing 3-Dimensional information for each of NDCDB's Surveyed Lot, Boundary and Station.

(ii) The issues relating to the validation and checking of heights. In other words, it is challenging determining the accuracy of height measured.

(iii) Issues retain to spatial, non-spatial records. The NDCDB currently resides in Oracle 10g RDBMS in all its 13 JUPEM States. The RDBMS contains spatial, non-spatial, as well as raster records that form the basis of ekadaster System. Because Oracle is a proprietary technology, it attracts recurrent maintenance cost. This will weigh heavily on the future sustainability of the platform. To address this challenge and in line with the latest development in open source RDBMS, JUPEM intends to investigate the open source RDBMS's capabilities in providing a more efficient, comprehensive, robust and cost-effective means of NDCDB storage, query, manipulation and output production, including spatial, non-spatial, as well as raster records.

(iv) Concerns about the methods of data collection, calculation and adjustment of existing survey the generation of 3D information (X, Y, Z). Currently, the height 'Z' of a boundary mark is referenced to the mean sea level. Thus, the methods of data collection, calculation and adjustment of existing survey and processing data needs to be changed for the purposes of implementing 3D cadastral database and producing 3D certified plans.

(v) The challenge of conforming to the FIG recommendation, which requires the development of a comprehensive Land Administration Domain Model (LADM) that supports 2D and 3D cadastral registration.

At this stage, the logical question to ask is how will the current initiatives of data migration from 2D to 3D facilitate or help in the development of efficient land administration model and how will this help involved parties, both within one country and between different countries, to communicate, based on the shared vocabulary (that is, an ontology) implied by the model? This paper attempt to answer some of these questions.

The next section discusses the methodology adopted to logically explore the initiative of Malaysian government by focusing on data migration from existing database to open source data base and the application modules for implementation of 3D cadastral system and 3D cadastral database by using open source platform. The section that follows discusses the role of LADM in 2D and 3D cadastral registration. The subsequent sections discuss the challenges of adopting LADM in cadastral registration, Available technologies in support of LADM, strategies to realize improved and efficient land management using LADM in Malaysia.

## 2. METHODOLOGY

The motivation for this paper is to discuss the current initiative of Malaysian government in providing the practical pathway towards realising an LADM-based 3D cadastral system in alignment with jurisdictional settings of Malaysia. It focuses on data migration from existing database to open source data base and the application modules for implementation of 3D cadastral system and 3D cadastral database by using open source platform. In developing the prototype system, the project investigates how the current 2D NDCDB should be upgraded to 3D and how the current workflows and associated data to be modified to support the realisation of the 3D cadastral system. In doing so, this paper aims to document the requirements of – Malaysian mapping agency –The Department of Survey and Mapping Malaysia (JUPEM) and its stakeholders for the process of upgrade. The methodology for the documentation includes reviewing JUPEM documents and workflow, review of online resources, visit to JUPEM and interview with experts in JUPEM.

## 3. THE ROLE OF LADM IN 2D AND 3D CADASTRAL REGISTRATION

The Land Administration Domain Model (LADM) is now the ISO standard and most recognizable data model in land administration discourse. This data model has been under development since the early 2000s. The model aims to provide an extensible basis for the development and refinement of efficient and effective land administration systems and to enable involved parties, both within one country and between different countries, to communicate, based on the shared vocabulary implied by the model (ISO19152, 2012). The concept is adaptable to, for instance, accommodating agricultural land use for purposes of the agricultural subsidy in the European Union, and recognizing the social tenures used in many countries by traditional, customary, and tribal people through the Social Tenure Domain Model (Lemmen, 2010).

Peninsular of Malaysia is consists of eleven states and three Federation states. State Land and Mines Office lead land administration in each state (Pejabat Pengarah Tanah dan Galian-PTG). Each Land Office has a slightly different method to register land. Land Offices register only legal (administrative) or ownership data. They are also different compare to how JUPEM (the Department of Survey and Mapping Malaysia) registers land. JUPEM collects and registers spatial (cadastral) data. Land Offices own eLand system and JUPEM owns eKadastre system.

LADM can be used as a common model to increase interoperability between different Land Offices and JUPEM in a national and international level. This would consequently improve the exchange of land information not only in between local and national, but international organizations as well.

### 3.1 Core objects of LADM

LADM has four basic classes. These are: LA_Party, LA_RRR, LA_BAUnit, and LA_SpatialUnit (ISO19152, 2012). The data sources are all documents providing legal and/or administrative facts on which the land administration objects such as rights, restrictions, responsibility, basic administrative units, parties, or spatial units are based on. Deeds, titles, mortgages, agreements are examples of administrative or legal documents. LADM has a solution to represent stratified interests and 3D parcels using Class LA_BoundaryFace. However, LADM does not use solid geometry (GM_Solid) to represent 3D parcels. Pouliot et al (2011) suggests how solid representation can increase LADM's 3D functionalities. Solid geometry facilitates 3D representation, volumetric calculation, and 3D spatial analysis.

### 3.2 LADM development and importance

As an international standard, LADM provides a conceptual and formal language for describing both semantic and spatial information associated with RRR affecting pieces of land or water, buildings, and airspaces (ISO19152, 2012). LADM seeks two main goals. First, it lays the foundation for effective and progressive design and development of a land administration system for those countries which currently do not have advanced infrastructure for managing land and property information. Second, LADM attempts to establish a common language to facilitate communication among land administration actors within one jurisdiction or across various jurisdictions. Three packages, namely Party, Administrative, and Spatial Unit, and one sub package, Surveying and Spatial Representation, constitute conceptual schema of LADM (Lemmen et al, 2015, p. 538).

The Party package includes entities for modelling information about different land administration actors (LA_Party) as well as their roles. These actors could include human or organizational actors. Owner, surveyor, notary or conveyancer could be examples of roles assigned to actors. The administrative package includes two distinct fundamental concepts, namely RRR (LA_RRR) and basic administrative unit (LA_BAUnit). The RRR concept is specialized into "LA_Right", "LA_Restriction", and "LA_Responsibility" which are used for modelling various types of rights, restrictions, and responsibilities respectively. The concept of basic administrative unit is adopted in LADM to arrange and combine spatial units with the same or homogenous RRR. In other words, RRR information assigned to a basic administrative unit shall be unique (Paulsson & Paasch, 2015). For instance, spatial units of an apartment unit, its car parks and storage areas can be assembled in one basic administrative unit which represents a privately hold property right within a multi-level building.

The Spatial Unit package and its Surveying and Representation sub package are used for modelling spatial dimension of legal objects. The fundamental entity in this package is "LA_SpatialUnit" which is used for modelling the concept of spatial units (Lemmen et al, 2015). This overarching concept includes various spatial representations of ownership interests defined inside any jurisdiction. These representations can be textual descriptions, sketch maps, points, unstructured set of lines, areal and volumetric legal objects (ISO19152 2012, p. 82). In the context of 3D RRR data management, there are two specialized concepts of spatial units, namely building units (LA_LegalSpaceBuildingUnit) and utility networks (LA_LegalSpaceUtilityNetwork). Here, a building unit refers to legal space defined for a building or a part of it, which is not essentially equivalent to the physical representation of the building. Likewise, the concept of utility networks in LADM represents legally defined spaces of utilities, which do not essentially equate with their physical counterparts. The Surveying and Representation sub package is mainly used to model topology of boundaries defining spatial units (ISO19152, 2012, p. 32) (see Figure 1). There are four key entities in this sub package: LA_Point, "LA_SpatialSource", "LA_BoundaryFaceString", and "LA_BoundaryFace". "LA_Point" is used for modelling points, which would either represent the location of a spatial unit or define a vertex of 2D or 3D boundaries. "LA_SpatialSource" provides information about a set of observations and measurements associated with points. These measurements include distances, azimuths, GPS coordinates and so on.

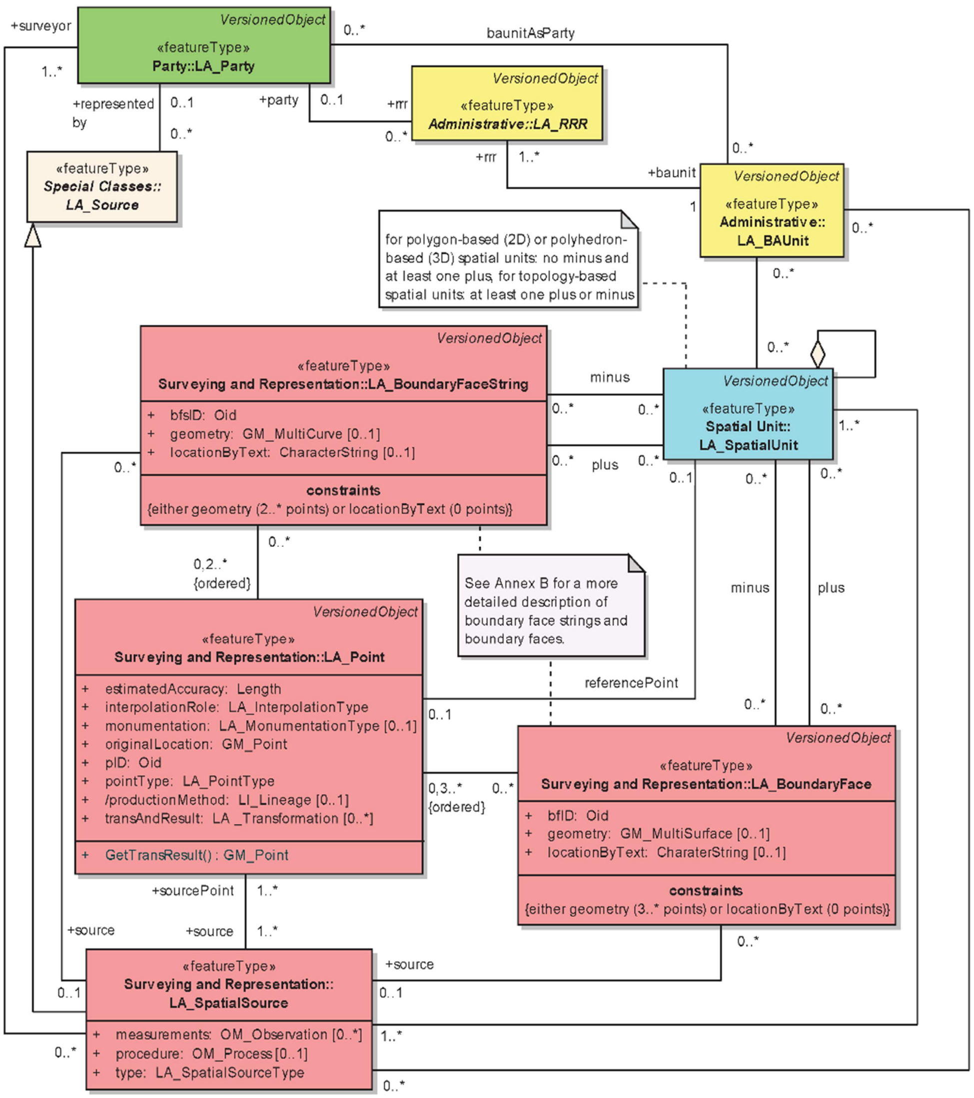


**Figure 1. Basic entities defined in Surveying and Representation subpackage**
*Adapted from (ISO19152 2012, p. 11)*

"LA_BoundaryFaceString" is adopted for modelling geometry of curve boundaries through its association with "LA_Point" and "LA_SpatialSource" entities. Curve boundaries must be defined by at least two points since start and end points of a curve is required in the simplest case. "LA_BoundaryFace" is used to represent the geometry of surface boundaries through its association with "LA_Point" and "LA_SpatialSource" entities. A surface boundary must be defined by at least three points. This is because a triangle is the simplest type of surface boundary and three points are required to form a triangle.

### 3.3 Current development of 3D cadastral registration in Malaysia

Currently, 3D cadastral registration in Malaysia is being done using strata plans for aboveground properties and stratum plans for underground properties.

#### 3.3.1 Strata plans for 3D cadastral registration

Strata plans provide the spatial dimensions of assets and properties located above ground. These plans provide legal spaces and legal boundaries for each level of a multi-storey development. There are three categories of data elements in strata plans, namely: legal interests, legal boundaries and legal attributes. In strata titles, various legal interests are defined. These include land parcel, parcel unit, common property, and accessory unit. Land parcel in this case refers to strata unit which is defined inside a master lot with a building with no more than four storeys. Parcel unit refers to an individual unit within an apartment or condominium. Parcel units are represented in white with red boundaries Figure 2.

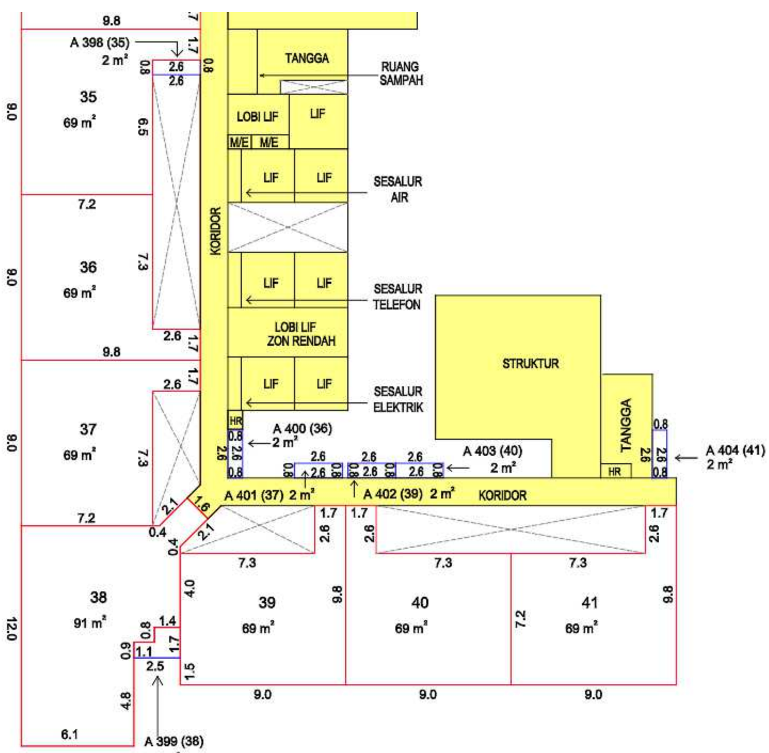


**Figure 2. Example of parcel units in a strata plan**

An accessory unit is a unit which is shown in a strata plan and will be used in conjunction with a parcel unit. A common property refers to those parts of a master lot which is not included in any individually owned unit including accessory units. Limited common properties must be exclusively used by a specific group of owners of strata lots. Legal boundaries define spatial extent of each legal interest. These boundaries in strata plans are boundaries that are specified based on surveying measurements such as distance, angle and azimuth. Within apartments, legal boundaries are defined as median lines inside physical structures such as walls and ceilings. Legal boundaries for parcel units, accessory units, and common properties are represented in red, blue and black, respectively Legal attributes are required for managing information about legal interests and legal boundaries. Some attributes are common among all legal interests, while other attributes are required for each specific legal interest.

### 3.3.2 Stratum plans for 3D cadastral registration

Stratum surveys in conjunction with disposal of underground land is provided for, under National Land Code 1965. For this purpose, underground stratum alienation involves the alienation of a solid volume of land at specified depth under the surface of the earth.

Stratum plan is prepared based on 'as-built' surveys comprising of the following:

1) Stratum location plan: This plan depicts the location in which the stratum structure is constructed according to a suitable scale based on the cadastral map or standard sheet. The plan should contain the following information: title, scale, adjacent lot and, direction.
2) Stratum Plan: The following information should be provided in the stratum plan (Figure 3 below):
   - Bearing and distance of the lot boundary in relation to the stratum structure;
   - Position of two (2) benchmarks showing heights reference to vertical reference datum;
   - Position of adjacent lots and the adjacent stratum lots (if any). The adjacent stratum lots should be shown in dashed lines;
   - Name and offsets to the road (if any);
   - Cross section (a-a, b-b) to indicate the stratum lot;
   - Vertical sections from two sides showing the heights / elevations of the stratum lot;
   - Isometric diagrams of the stratum with coordinates and volumes shown.
3) Utilization Plan: The plan should contain the following information:
   - Isometric diagram;
   - Heights;
   - Schedule of stratum utilizations;
   - Floor plan.
4) Stratum Access Plan: The plan should show the following information (Figure 4 below):
   - Bearing and distance of the lot boundaries in relation to the stratum;
   - Position of two (2) benchmarks depicting heights reference to vertical reference datum;
   - Position of lots and adjacent stratum lots (if any). The adjacent stratum lots should be shown in dashed lines;
   - Name and offsets to the road (if any);
   - Isometric access diagram;
   - Coordinates for each access corner.

Easement registration document is required if access is needed in relation to neighboring lots.

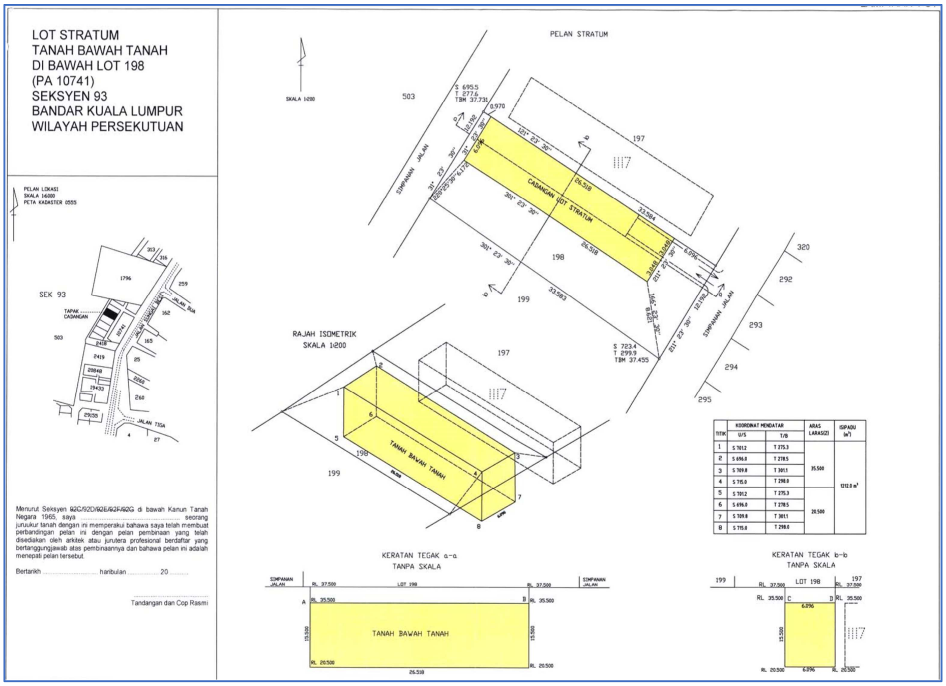


**Figure 3. Stratum Plan**

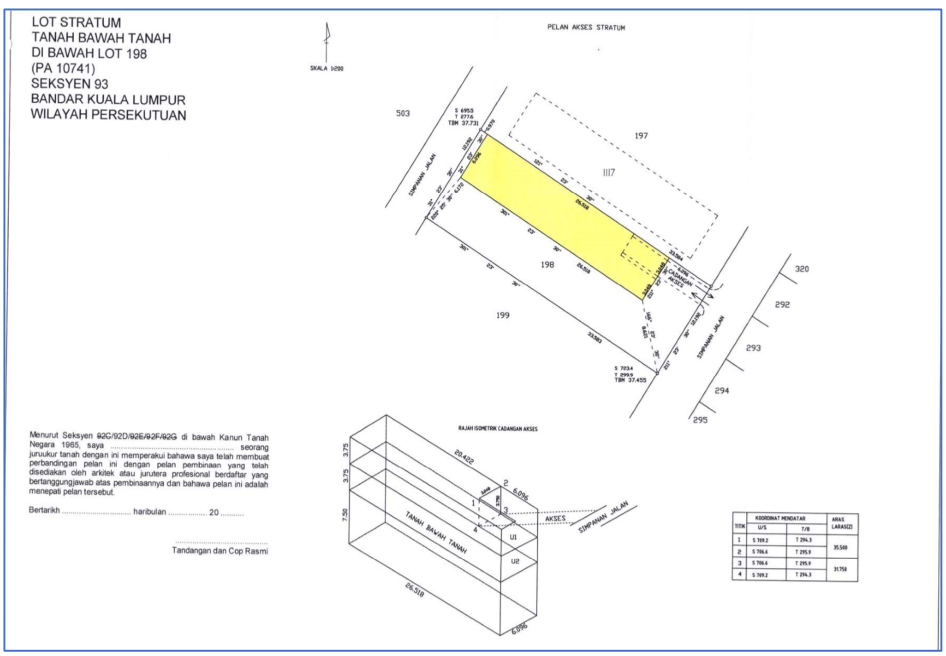


**Figure 4. Stratum Access Plan**

## 4. ISSUES OF CURRENT 3D CADASTRAL REGISTRATION IN MALAYSIA

Appearance of complex and multi-store underground and above ground built structures posed new challenges for Malaysian land administration systems in urban areas. In current Malaysia 3D cadastral practices, 2D paper based drawings such as cross-sections, isometric diagrams, and plans of subdivision are used to manage ownership information for properties located in the vertical dimension. These drawings include complicated textual information which is only understandable for specialized land surveying professions.

The complexity of this textual information affects the communication of ownership boundaries and results in inadequate understanding. Furthermore, enormous number of these documents is used to show ownership information about multi-layered properties in the vertical dimension.  Therefore, a lot of effort is being done to create access rights for all the properties in high-rise buildings. Moreover, the access to ownership information is slow and time-consuming task. The complex reality of inter-related titles and rights, restrictions and responsibilities (RRRs) associated with properties cannot be effectively shown by 2D paper based drawings and even 2D digital plans.

Another challenge is cost. Although current 2D approach is functional, it is costly because enormous 2D diagrams are used to describe, manage as well as visualize multi-layered, stacked land and property information in high-rise buildings. Furthermore, 2D approach is insufficient because 2D survey plans are difficult to understand and no longer usable for other stakeholders who are involved in the building development process and do not have any expertise in the land surveying profession. Current 3D models used by architects and engineers do not include any ownership information to be used in the land administration process. In order to address these challenges, Malaysian land administration agencies have been persuaded to adopt an LADM-based approach for 3D cadastral registration. However, adopting LADM has its own challenges

### 4.1 Challenges of adopting LADM in cadastral registration

ISO standard provides a guideline for adopting LADM in land registration. However, the following challenges exist: data structure and model, Land data schema. In addition to these, it could be observed that currently, measurements are stored in the National Digital Cadastral Data Base (NDCDB), which is a database of 2-dimensional (X, Y), Whereas objects are three dimensional and are, thus, required to be represented in 3D. Also, the methods of data collection, calculation and adjustment of existing survey and processing data needs to be changed for the purposes of implementing 3D cadastral database and produce 3D certified plans.

## 5. AVAILABLE TECHNOLOGIES IN SUPPORT OF LADM

There have been many researches on LADM to adequately handle registration and maintenance of various types of land information related to legal, administrative, and technical aspects (Kim and Heo, 2017; Gogolou and Dimopoulou, 2015; Inan, 2015;

Kalantari et al, 2015; Paasch et al, 2015; Thompson, 2015; Van Oosterom and Lemmen, 2015, Lemmen et al, 2016, Vučić et al, 2017). Among those three aspects, Paulsson and Paasch (2015) discussed that technical aspect has been in focus between 2001-2015. They classified the technical category into spatial data infrastructure (SDI), data models, database management, exchange formats and the technical aspects of distribution and delivery GIS, visualization and geometrical representation, cadastral surveying, geometry, topology. Among the above-mentioned categories, most of the research activities are related to data modelling and implementing LADM into country profiles (Bydłosz, 2015; Griffith-Charles et al, 2015; Lee et al, 2015; Mader et al, 2015; Zhuo et al, 2015; Zulkifli et al, 2015).

Although, most of the LADM data modelling implementations are limited to research and development in academia at this stage (Kalantari et al, 2015), some countries investigated and considered LADM as a possible data model for their cadastre related strategies. For example, Vučić et al (2017) raised the importance of legislation in implementation of technological options in cadastres. They conducted a research to analyse land-related registers in the Republic of Croatia to evaluate the condition of land-related data such as parcels, buildings, and utilities as well as rights, restrictions, responsibilities over those features and spaces. They aimed to determine the level of redundancy between the registers closely related to the domain of land administration and LADM was used for this purpose. In addition, a detailed analysis of the current legislation was conducted. As another example, in Czech Republic, GeoInfoStrategy was developed based on LADM for effective use of the spatial data in public administration to fulfil the government priorities in the fields of environmental protection, cadastre, and protection of cultural heritage (Janečka and Souček, 2016).

Some researchers have moved beyond the theoretical research and implemented a prototype system based on LADM. For example, a prototype system has been developed in Kenya using free and open source software (FOSS) (Kuria et al, 2016). The open source tools used for the implementation include: Dia (for Unified Modelling Language (UML) Modelling), PostGIS and PostgreSQL (for database development and management); QGIS (for GIS data preparation, management and cleaning); Liclipse (as the Integrated Development Environment) and Leaflet, Mapnik, Geodjango & Django (for the web map application development). Python programming language was used for writing the code for the system implemented. This system was developed as a web application using the Django Python Framework tools. The tools used in the implementation are listed in Figure 5 below.

These tools range from modelling tools, database development and management tools, GIS data preparation, cleaning and management, Integrated Development Environment and Web application development tools. The pilot solution uses a web centric solution, with the data stored and managed centrally from a PostGIS database backend, using the Python Django framework to implement the server side and client-side frontend. This solution demonstrates the importance of automating processes and supporting standards based software development.

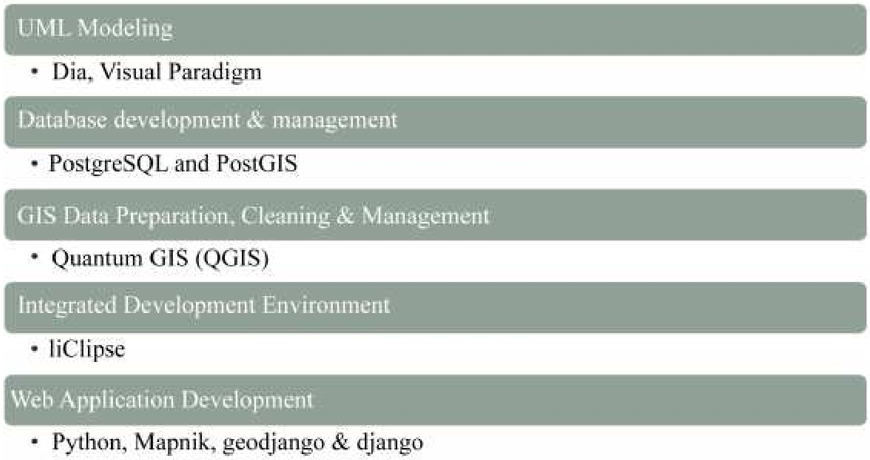


**Figure 5. Software applications used in Kenya for development of an LADM prototype system (***Kuria et al, 2016***)**

As another example, Zulkifli et al (2014) presented an LADM prototype system in Malaysia which used some sample data from Department of Surveying and Mapping Malaysia (JUPEM) and land office. Database construction was based on Oracle spatial. The prototype frontend development was based on Bentley Microstation. This prototype had limited functions and only covers small area for the assessment of the Malaysian LADM country profile. Initial result of the prototype for 3D strata objects registration as illustrated in Figure 6.

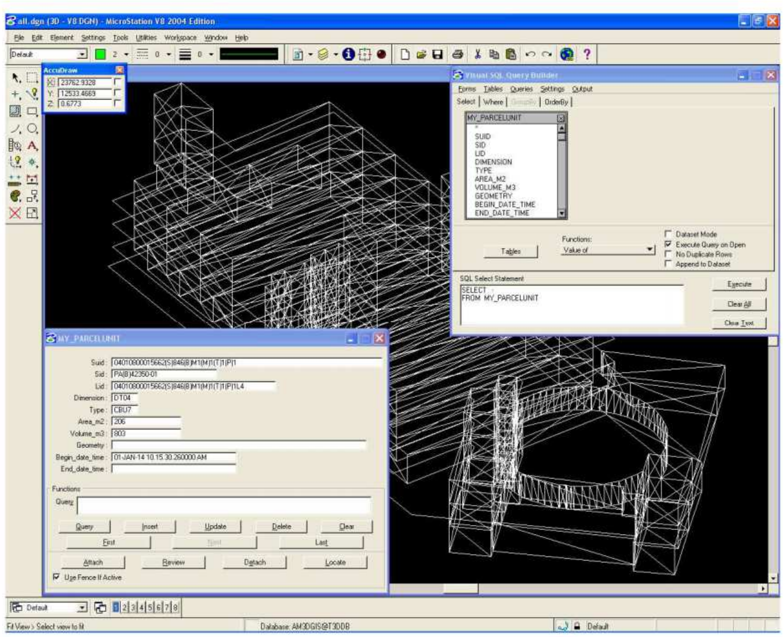

**Figure 6. 3D data query and visualization of MY_ParcelUnit using Bentley Microstation**
*(Zulkifli et al, 2014)*

Lemmen et al (2016) proposed the Service Oriented Architecture (SOA) as an enterprise architecture for developing fit-for-purpose land administration systems in less developed countries to secure tenure.

LADM has also been formulated in INTERLIS and the result is a layered INTERLIS data model. Using INTERLIS tools, databases such as Oracle and PostgreSQL can be used and also a data exchange format according to that specific LADM country can be utilised. By applying INTERLIS to LADM, it can significantly speed up the implementation of LADM in a jurisdiction. As INTERLIS tools (compiler, checker, UML-Editor) and specifications are free, the LADM/INTERLIS method can easily be implemented with a lower cost (Germann et al, 2015).

## 6. REALISING IMPROVED AND EFFICIENT LAND MANAGEMENT USING LADM IN MALAYSIA

Adopting an LADM-based approach in Malaysian jurisdiction would facilitate 3D cadastral registration in complex ownership situations. The advantages of using LADM for 3D cadastral registration in Malaysia are:

1. LADM can provide 3D digital representation of legal space associated with each property located in complex urban developments. This would help easily communicate legal ownership of complex properties with inexpert stakeholders, particularly owners and facility managers, involved in property and building management.
2. LADM would support efficient harmonization of 2D and 3D cadastral information from different jurisdictions. This standard can act as a common language among various jurisdiction to easy share and use cadastral information with each other in digital environments.
3. As current strata and stratum subdivision practices in Malaysian jurisdictions are based on 2D-based analogue plans, adopting an LADM-based approach could potentially advance current subdivision practices into 3D digital, intelligent and dynamic data environments.
4. Re-using cadastral information from current 2D-based subdivisions plans is quite cumbersome since the data environment is analogue. However, LADM-based 3D digital cadastral information can be re-used after the registration phase. For instance, when a piece of land is being subdivided or consolidated, the 3D digital subdivision plan for the existing developments within or in the vicinity of that land parcel can be re-used without further efforts.

## 7. STRATEGIES FOR THE IMPLEMENTATION OF 3D-NCDB

To achieve the above, it is better to articulate the process of upgrading the existing dataset and data collection methods to support the 3D digital data and the creation of 3D spatial database based on the elicited user requirements. The adopted approach will support the integration of complementary modules, especially for 3D spatial data input, 3D adjustment and validation of 3D spatial data. The implementation of 3D-NDCBD is an initial step to develop 3D Kadaster

System that includes the upgrade of the hardware, software and application modules to support 3D data.

The proposed 3D platform is intended to be designed as a parent system or project that will support the integration of complementary modules, especially for data input, adjustment and validation of data. All the modules: ePU, eQC, eSPEK and DRP are refined, for efficiency and proper functioning. All these will be framed and enhanced by the LADM framework. The system when fully developed will integrate with several other systems, internally within JUPEM and externally with other organizations and agencies of government.
The process of upgrading to 3D database could be illustrated with 7 components and 4 minor processes as shown in Figure 7.

As illustrated, the existing data should be converted to 3D data using 3D authoring tool which would be explained in the next subsection. Additionally, the data collection (survey) method should be upgraded to meet the requirement for 3D data collection. The 3D authoring tool will provide the capability to create 3D digital representation of parcels from existing 2D datasets and collected 3D data.

The visualization application consists of two components. The 3D visualization component would receive the required 3D models and visualize them. This component could be developed based on web technologies which is open-source and more accessible.

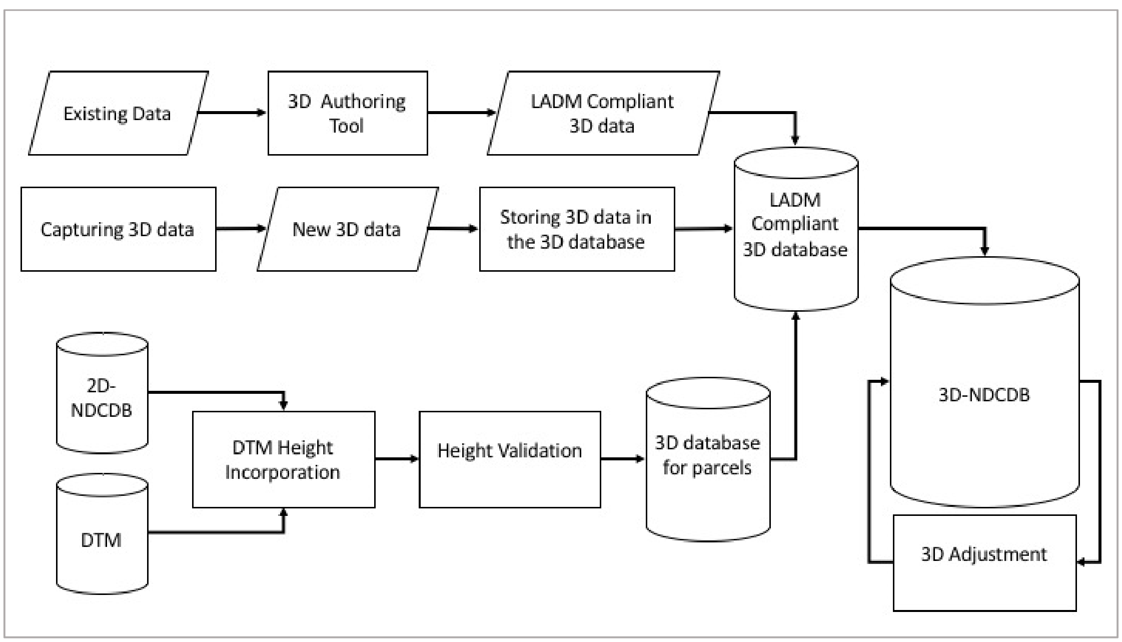


**Figure 7. Proposed implementation of 3D-NDCBD (flow chart)**

## 7. DISCUSSIONS AND CONCLUSIONS

LADM as an international standard presents itself as an opportunity to improve the land administration system of Malaysia. The improvements and benefits that LADM can bring about to Malaysia in multifaceted.

- ***Preparing land tenure data to measure indicators related to Sustainable Development Goals:*** The UN's Sustainable Development Goals (SDGs) is a major driver for harmonising geospatial information at the international level. Among the information, land tenure is a critical piece for measuring several indicators related including but not limited to poverty, gender equality and life on land. The LADM can be used a way of normalising the land tenure information for Malaysia so the consistent comparisons can be made between Malaysia and the other countries in terms of SDGs.
- ***Harmonizsing land tenure data at the national level:*** Internal operations of land offices in Malaysia vary as such the way land administration data is recorded and used are different. This has resulted in database systems that are different in structure and schema. While it may not be practical or viable to make the databases consistent at the national level, LADM provides an opportunity for harmonizing the data when there is a need to integrate the databases for national interests. Database systems of the land office can be mapped to LADM to provide a common ground for understanding how different data elements are described and used. This understanding will lead into more straightforward integration of land titling data at the national level.
- ***Introducing 3D cadastres:*** 3D digital cadastral system is on the agenda of JUPEM and can be approached from three perspectives and LADM can be used a benchmark as how the new data requirements shall be managed. First, upgrading the strata plan system to a fully 3D digital plan, second advance the paper-based stratum plans to 3D digital volumetric lots and third, transforming 2D data collection system of land surveying in Malaysia into a 3D data collection regime. First and second approach do not fundamentally change the principles of cadastral surveying in Malaysia and they are incremental changes. However, the third approach is transformational and can change how cadastral surveying perceived and undertaken. Either incremental or transformational, there will be new data requirements in land registration and cadastre and the LADM can guide as how the new data requirements shall be factored and integrated to the existing data.

If the government of Malaysia adopts LADM, it will put itself at forefront of international land administration reform. The leadership will assist with the initiative such as SDGs that have a longstanding impact on the social stability, economic prosperity and environmental sustainability of the countries in the world. The adoption of LADM will also benefit the tax payer of Malaysia as it reduces the resources required to make the land tenure data consistent in the country. The data will be more reliable and more value-added service can be derived from such a data.

Finally, reforming the land administration of Malaysia to a system that incorporates the 3rd dimension of height into the cadastral surveying and titling systems, needs a benchmarking system such as LADM so the data requirements of the reform are well understood and factored in the reform.

## REFERENCES


Aien, A., Rajabifard, A., Kalantari, M. and Williamson, I. (2017). Review and Assessment of Current Cadastral Data Models for 3D Cadastral Applications. In A. Abdul-Rahman (eds.), Advances in 3D Geoinformation; Springer, 423- 442.

Bydłosz, J. (2015). The application of the Land Administration Domain Model in building a country profile for the Polish cadaster. Land Use Policy, 49, pp. 598-605.

Germann, M., Kaufman, J., Steudler, D., Lemmen, C., Van Oosterom, P. and De Zeeuw, K. (2015). The LADM based on INTERLIS. WCS-CE - The World Cadastre Summit, Congress & Exhibition Istanbul, Turkey, 20 –25 April 2015.

Gogolou, C. and Dimopoulou, E. (2015). Land Administration Standardization for the integration of cultural heritage in land use policies. Land Use Policy, 49, pp. 617-625.

Griffith-Charles, C., Mohammed, A., Lalloo, S. and Browne, J. (2015). Key challenges and outcomes of piloting the STDM in the Caribbean. Land Use Policy, 49, pp. 577-586.

Inan, H.I. (2015). Associating land use/cover information with land parcels represented in LADM. Land Use Policy, 49, pp. 626-633.

Janečka, K. and Souček, P. (2016). Country Profile for the Cadastre of the Czech Republic Based on LADM, Czech Republic. 5th International FIG 3D Cadastre Workshop 18-20 October 2016, Athens, Greece

Kalantari, M., Dinsmore, K., Urban-Karr, J. and Rajabifard, A. (2015). A roadmap to adopt the Land Administration Domain Model in cadastral information systems. Land Use Policy, 49, pp. 552-564.

Kim, S. and Heo, J. (2017). Development of 3D underground cadastral data model in Korea: Based on land administration domain model. Land Use Policy, Volume 60, pp. 123-138.

Kuria, D., Ngigi, M., Gikwa, C., Mundia, C. and Macharia, M. (2016). A Web-Based Pilot Implementation of the Africanized Land Administration Domain Model for Kenya—A Case Study of Nyeri County. Journal of Geographic Information System, 8, pp. 171-183.

Lee, B., Kim, T., Kwak, B., Lee, Y, and Choi, J. (2015). Improvement of the Korean LADM country profile to build a 3D cadastre model. Land Use Policy, 49, pp. 660-667.

Lemmen, C, Enemark, S., Mclaren, R., Antonio, R., Gitau, J., Dijkstra, P. and De Zeeuw K. (2016). Guiding principles for building fit-for-purpose land Administration systems in less developed countries: Providing secure tenure for all, 2016 World Bank Conference on Land and Poverty" The World Bank - Washington DC, March 14-18.

Mađer, M., Matijević, H. and Roić, M. (2015). Analysis of possibilities for linking land registers and other official registers in the Republic of Croatia based on LADM. Land Use Policy, 49, pp. 606-616.

Paasch, J.M., Van Oosterom, P., Lemmen, C. and Paulsson, J. (2015). Further modelling of LADM's Rights, Restrictions and Responsibilities (RRRs). Land Use Policy, 49, pp. 680-689.

Paulsson, J. and Paasch, J.M. (2015). The Land Administration Domain Model – A literature survey. Land Use Policy, 49, pp. 546-551.

Thompson, R.J. (2015). A model for the creation and progressive improvement of a digital cadastral data base, Land Use Policy, 49, pp. 565-576.

Van Oosterom, P. and Lemmen, C. (2015). The land administration domain model (LADM): motivation, standardisation: application and further development. Land Use Policy, 49, pp. 527-534.

Vučić, N., Roić, M., Mađer, M., Vranić, S. and Van Oosterom, P. (2017). Overview of the Croatian Land Administration System and the Possibilities for Its Upgrade to 3D by Existing Data. ISPRS International Journal of Geo-Information 2017, 6(7), 223. doi:10.3390/ijgi6070223

Zhuo, Y., Ma, Z., Lemmen, C. and Bennett, R.M. (2015). Application of LADM for the integration of land and housing information in China: the legal dimension. Land Use Policy, 49, pp. 634-648.

Zulkifli, N.A., Abdul Rahman, A., Van Oosterom, P., Tan, L.C., Jamil, H., Teng, C.H., Looi, K.S. and Chan, K.L. (2015). The importance of Malaysian Land Administration Domain Model country profile in land policy. Land Use Policy, 49, pp. 649-659.

Zulkifli, N.A., Abdul Rahman, A. and Van Oosterom, P. (2014). 3D Strata Objects Registration for Malaysia within the LADM Framework. 4th International Workshop on 3D Cadastres, 9-11 November 2014, Dubai, United Arab Emirates.

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