DEVELOPING INFRASTRUCTURE FRAMEWORK FOR 3D CADASTRE

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Abstract

One of the important global issues with regard to property is the scarcity of vacant land for development. Many countries, including Malaysia, do not have enough vacant land on the ground surface to cater for rapid development. In the last couple of decades, there has been an increasing demand for property development in urban areas, resulting in the division of property ownership so that different owners can own a delimited space on, above or below ground surface. Under 3D cadastre, the 2D cadastre management of data cannot meet the real land management of the three dimension space aspect and property. It is essential to introduce the 3D cadastre of Three-Dimensional National Digital Cadastral Database (3D-NDCDB) management model. Since the individualisation of property has traditionally been concerned with the subdivision of land using on surface boundaries in the cadastral system, it is appropriate now to consider how three-dimensional situations should be handled from the legal, technical and organisational aspects, and how other countries have addressed similar issues.

Key words: *Three-dimensional (3D)[1], cadastre[2], National Digital Cadastral Database (NDCDB)[3]*

1. INTRODUCTION

The primary objective of eCadastre is to expedite the delivery system for land title surveys. This entails the creation of a survey accurate database at the national level suitable for Geographical Information Systems (GIS) users. Various issues related to the generation of a survey accurate database need to be addressed. The vision of Malaysia becoming a developed country by 2020 calls for the realisation of an efficient public delivery system at various levels. Among the issues of national interest are land related matters, which include cadastral surveys. The government approved an eCadastre project under the 9th Malaysian Development Plan (2006-2010) to be implemented by the Department of Survey and Mapping Malaysia (DSMM), in line with the government's aspiration to have a fully digital Malaysia by 2015.

Since 1995, DSMM has embarked on a modernisation program that saw the dramatic computerisation of both its office and field processes of its cadastral survey division. The Digital Cadastral Database was created by capturing the surveyed accurate information of all land parcels. Under the eCadastre project, a comprehensive nationwide readjustment of the meshwork of parcels will be carried out based on a new geocentric datum concept. The Real Time Kinematic Global Positioning System (RTKGPS) has seen the setting up of permanent stations established to provide precise geocentric positioning to assist the Coordinated

Cadastral System implementation. This network is to be implemented to support the eCadastre project.

The current system of cadastral survey is yet unable to capitalise on the advent of satellite based technologies. A complete revamp of the system is required before any improvement to the delivery system could be achieved. The new environment will allow various cadastral survey processes, such as planning, layout design submission, field data capture, completed job submission, quality control and approval, to be carried out remotely via the mobile telecommunication network. Global Positioning System (GPS) will provide real time positioning at centimetre resolution homogenously for the entire country and coordinates will replace relative measurements as the ultimate proof of boundary mark position. Additional features such as building footprint and space images will be incorporated into the new database in a move towards a multipurpose cadastre.

There are three main components in eCadastre, namely Coordinated Cadastral System, Virtual Survey System and Cadastral Data Integrity System. The implementation of a Coordinated Cadastral System is a major part of the eCadastre project that includes field and office reengineering to reduce processes and increase the use of digital technology. The Virtual Survey System will equip the field surveyor with ICT, total station, GIS and GPS. The surveyor will be able to interact with the system to extract information that is essential in field operations. Most of the work is automated to reduce tedious computation.

Meanwhile, Cadastral Data Integrity System comprises all the office application related to cadastre, which include pre-survey verification, field survey data computation and verification, digital title plans generation and approval. In order to implement multipurpose 3D cadastre in Malaysia, new requirements are needed to capture the data in three-dimensional (on surface, above surface and below surface) to cater for strata, stratum surface. This process will be performed in the Electronic Strata Module consisting of the Strata Lodgement Module, Electronic Strata Survey Module and Strata Verification Module. The Strata Lodgement Module is developed especially to fulfil the requirement of a spatial database for strata, while the Electronic Strata Survey Module is developed to perform strata job verification on the ground and at same time perform data collection, and the Strata Verification Module is developed mainly to fulfil the needs of spatial usage for data checking from field checks.

2. BACKGROUND

Multiple use of land is increasing. The owner of a parcel of land may possess the rights to the column of air above and the column of soil under that land. At ground level, multiple use of land has resulted in the multiple exercises of rights of the use of the regions above and below ground level and in the division of rights in the ownership column.

The consideration which is studied in most countries for the achievement of an unambiguous determination of 3D cadastre issue starts gradually from the existing 2D cadastre system, leading to a better understanding of the legal, organisational and factual situations above and below the ground surface. Moreover, as mentioned by Aydin, Demir and Atasoy (2004), the use of three-dimensional data in applications to register properties, property rights of objects in geometrical and legal situations, parcel based three-dimensional information systems should be supported by three-dimensional information. Hence, legal and organisational aspects in the 3D cadastre system are preliminary to other aspects.

2.1 The Importance of 3D Cadastre

Current cadastre registration systems, bound to ground surface topological and geometrically described parcels, have shown limitations in providing an insight into three-dimensional location of three-dimensional constructions as well the vertical dimension (depth and height) of rights established for three-dimensional constructions (Stoter, 2004). In addition, the cadastre should be able to describe property ownership, including Strata Title ownership.

A 3D cadastre is defined as a cadastre that registers and gives insight into rights and restrictions not only on parcels, but also on 3D property units (Stoter, 2004). Thus, a 3D cadastre would be able to handle such conditions as overlapped buildings and utilities that prohibit the property from being registered according to legal and organisational aspects using a 2D cadastre.

In the near future, the cadastre will contain updated documentation of public and private rights, ownership, land use and real estate in various spaces. Concurrently, Benhanu and Doytsher (2003) contend that the 3D boundaries and parcels in space will be determined by the 3D cadastre that serves the legal and physical objectives. A modern cadastre system should always reflect the existing situation of all property rights, including a mixture of private and public properties. It should provide a better-rationalised management of the built environment, including regulations of legality of use or of economic application (Dimoponlou, Gavanas and Zuntelis, 2006).

In order to better represent this evolving situation, it is necessary to develop a 3D cadastre with its own legal solutions that meet its specific needs. On the other hand, the content and role of a cadastre that is related to three-dimensional properties have not changed significantly, notwithstanding the substantial impact on the cadastre system. These impacts come mostly from global economic, social, technological factors as well as the need for sustainable development. The 3D cadastre system should provide information beyond the typical planning data and ensure registered rights above, on and below the surface of a property. Hence, land will be more optimally developed and utilised.

Valstad (2006) notes that no country has fully established and implemented the required legal and organisational requirements to accommodate 3D cadastre comprehensively. At present, there are countries that have developed infrastructures that are based on 3D cadastres within their legal systems, organisational and technical needs. Valstad asserts that a few countries have new laws that provide for the registration of specialised three-dimensional parcels although the cadastre system itself is still of a two-dimensional nature. Norway and Sweden have passed laws that make it possible to register three-dimensional construction parcels. The same is true for the Netherlands, but registration does not apply to separate units. British Columbia in Canada and Queensland in Australia have provisions in their laws to subdivide properties situated on the same 2D coordinates.

2.2 Practical Solutions

Rapid urban development today is increasing the demand for three-dimensional boundaries to support the volume parcels in real property objects. However, problems may arise from the registration of 3D properties. Stoter (2004) proposes three fundamental concepts to cater to and resolve such problems, albeit with minor modifications to suit or match the cadastral survey, mapping registration system and land registration system to that of each country. The three fundamental concepts with several options are as follows:

(a) Full 3D cadastre
- Option 1: Combination of infinite parcel columns and volume parcels, i.e. a combined 2D/3D alternative.
- Option 2: Only parcels that are bounded in 3D volume.

(b) 2D/3D hybrid cadastre
- Option 1: Registration of 2D parcels in all cases of real property registration, and additional registration of 3D legal space in the case of 3D property units.
- Option 2: Registration of 2D parcels in all cases of real property registration, and additional registration of physical objects.

(c) 2D cadastre with 3D tags linked to parcels in current cadastral registration.

3. OBJECTIVES

The purpose of this paper is to examine the possibility of implementing 3D cadastre system in Malaysia. One of the important principles in the development of cadastre system is the fully 3D land information surface. This addition information to the boundary marks in the NDCDB would create a 3D-NDCDB. In order to achieve the objective, some of these matters must take into consideration.

(a) Method of data collection;
(b) Adjustment and calculation of observed data;
(c) The products; and
(d) Changes to the format and structure of existing system.

It is hoped that this study will provide a better understanding of the nature of 3D-NDCDB, besides adding new information to the available literature in the field. I envisage the main contributions of this study to the present knowledge to be in the cadastral survey and mapping, and land registration practices in the Malaysian Cadastre System from the legislative and technical viewpoints.

4. TOWARDS MULTIPURPOSE 3D CADASTRE IN MALAYSIA

In recent years, a 3D cadastre registration system is being developed. Researchers have contemplated adding 3D cadastre objects in the current cadastre data model and information, accessible by the Department of Survey and Mapping Malaysia, State Land and Mines Office, and District Land Office. Unfortunately, the two stated databases, *viz.* the Cadastral Data Management System (CDMS) (eCadastre) and the Computerised Land Registration System (CLRS) (eLand) database work separately under different authorities, still do not support three-dimensional capability. As mentioned previously, the Malaysian Land Administration is based on the Torrens System where the cadastral map and the Document of Title with spatial and textual information are regarded as legal evidence, and are required under the rules and regulations in order to have full institutional coordination. Therefore, a good institution is very important in order to achieve an excellent and reliable cadastre registration system. However, due to historical constraints, it seems quite difficult to realise this unless there is full cooperation from various legal bodies, technical organisations and other land-related government agencies and private sector participants.

A multipurpose 3D cadastre can be defined as an integrated land information system containing legal (e.g. tenure and ownership), planning (e.g. land use zoning), revenue (e.g. land value, assessment and premium) and physical (e.g. cadastre) information. Therefore, the Malaysian multipurpose 3D cadastre should contain all information about administrative records, tenure, value and sale & purchases records, base maps, cadastral and survey boundaries, categories of land use, streets addresses, census utilities etc. It has the potential to support spatial enabled government, private sectors and society by expanding the process of visualisation, organisation and management of useful land information. In brief, there are many advantages for implementing a multipurpose 3D cadastre. It is especially useful for property inventory, project implementation and monitoring, utility management, population estimates, school management, census mapping and urban and rural development.

A 3D cadastre registration model has been proposed recently, focusing on the combination of these two cadastre registration databases and encompassing matters pertaining to legal rights, land attributes and spatial objects geo-data. The three authorities mentioned above are the main government agencies that are responsible for the cadastre registration system; they integrate and coordinate each other in order to have an integrated and comprehensive cadastral system in Malaysia by using a 2D/3D hybrid cadastre approach.

Various 3D cadastre objects, such as stratified buildings, and construction above and below the ground surface, are the responsibility of the Department of Survey and Mapping Malaysia and the State Land and Mines Office/District Land Office where it concerns object registration and ownership registration respectively. In short, 3D cadastre registration is a combination of land registration utilising the plan land parcel and the three-dimensional land parcel for cadastral registration. Three-dimensional cadastre registration encompasses considerations of the legal rights of land attributes, plane cadastral objects and three-dimensional information.

5. EMPIRICAL CASE STUDY

At present, the digitalisation has fully implemented in the department and is better known as National Digital Cadastral Database (NDCDB). NDCDB adopted now is a database of two-dimensional (2D) (X, Y), where the information is stored in 2D coordinate planimetric. To produce 3D (X, Y, Z) for each boundaries mark, methods of data collection, calculation and adjustment of traverse survey data need to be changed. The purpose of this paper is to examine the possibility of implementing 3D cadastre system in Malaysia. One of the important principles in the development of cadastral system is the fully 3D information of land surface.

This subsection will discuss a trial implementation for the Three-dimensional Digital Cadastral Database (3D-NDCDB) which allows a mixture of 2D and 3D cadastre. To begging, the aim is to provide land with 3D elevation data. This addition information add to the boundary marks in the NDCDB would create a 3D-NDCDB. To achieve this purpose, the matters to be addressed are as (a) Field Data Acquisition (b) Adjustment and Calculation of Observed Data (c) 3D-NDCDB, and (4) Changes of Format and Structure. For the purpose, a test project was carrying out in State of Negeri Sembilan, Malaysia.

5.1 Field Data Acquisition

The collection of traverse data in the field in eCadastre environment is fully digitalised. The current method of data collection is using Digital Field Book (BKD) interface. There are two main components of BKD, i.e. observation bearings and distances. Final bearing is produce from the Least Square Adjustment (LSA). Data collection to produce 3D coordinates requires additional information tools, i.e. observation of height of Total Station and prism. With this additional information, existing BKD must be changed to suit those needs. In the existing BKD, the terms of observations is "vertical angle", while the observations recorded are zenith angle values. To implement 3D cadastre, the use of vertical angle observations are more practical, which the surveyor can calculated the high difference in positive or negative value.

5.2 Adjustment and Calculation of Observed Data

Least Square Adjustment (LSA) in the cadastral survey in Malaysia has been fully utilized in eCadastre environment. However, the adjustment only involves 2D data. To produce 3D-NDCDB, an adjustment with 3D data should be doing. For this purpose, the observed data used and exported to an adjustment format are bearings, distances and high differences information. Coordinates (X, Y, Z) reference adopted in the formation of 3D-NDCDB must be compatible with the coordinate system used by eCadastre and MyGEOID. This compatibility is important that the height of product for each traverse boundaries have height information. For this purpose, the start station must have a value of orthometric height to allow the determination of orthometric height of the front station.

5.3 3D-NDCDB

The 3D-NDCDB products will be the basis of fully 3D cadastre implementation. Among the 3D-NDCDB initial products are as follow:

5.3.1 Height Information

Height information of each boundary mark (see Figure 1).

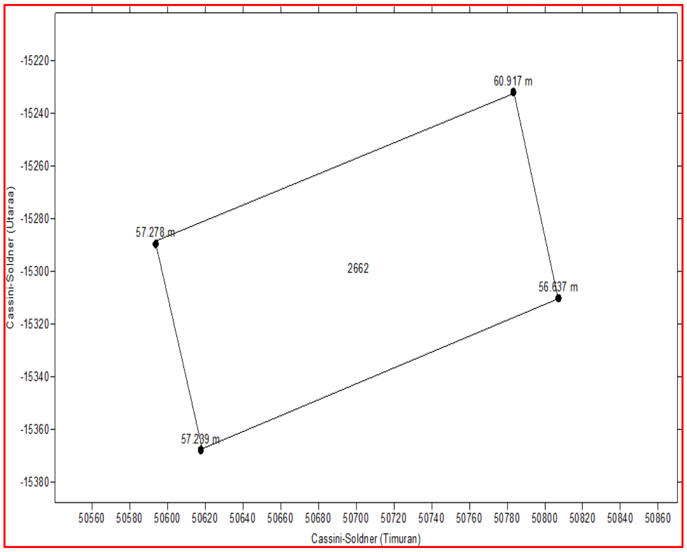

Figure 1: Example of height information

5.3.2 3D Certified Plan (3D-PA)

i) Contour information for each lot (see Figure 2)

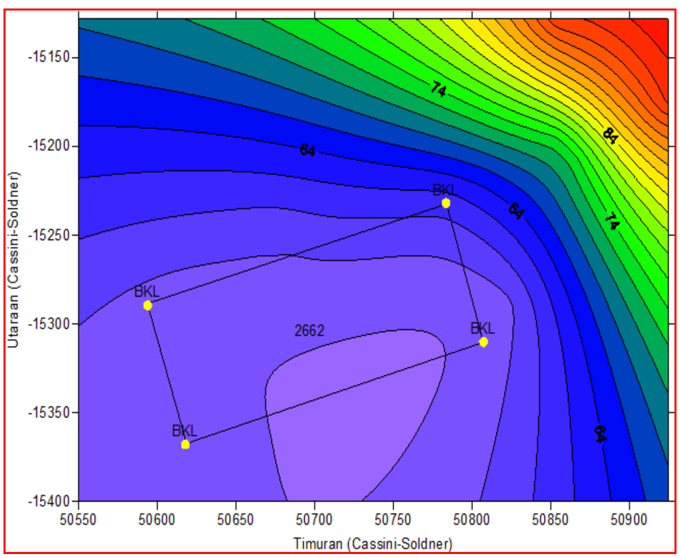

Figure 2: PA with contour lines

ii) 3D plot (see Figure 3)

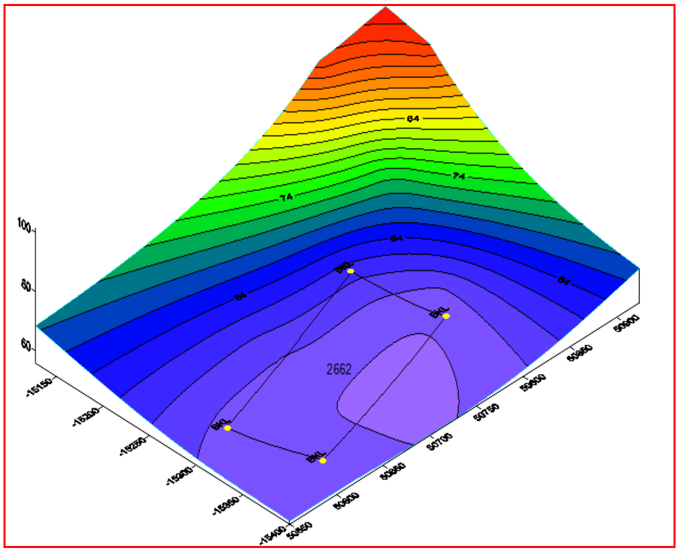

Figure 4: PA with 3D plot

iii) 3D wireframe plot (see Figure 4)

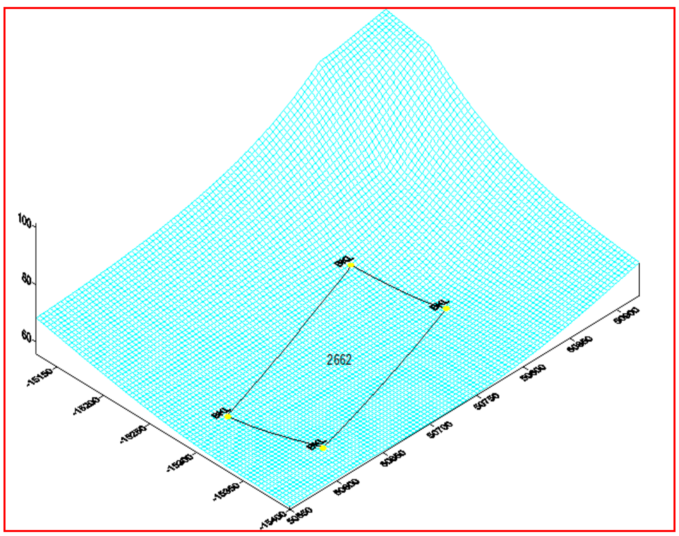

Figure 4: PA with 3D wireframe plot

5.3.3 <u>Certified Plan (PA) with Satellite Image</u>

Overlay plot with satellite imagery for surface analysis for landslide studies and consolidation of information from LIDAR or IFSAR grid (see Figure 5).

Figure 5: PA with Satellite Images

5.3.4 <u>Digital Terrain Model (DTM)</u>

Produce Digital Terrain Model (DTM), which is more accurate for use in the field of geodesy (see Figure 6).

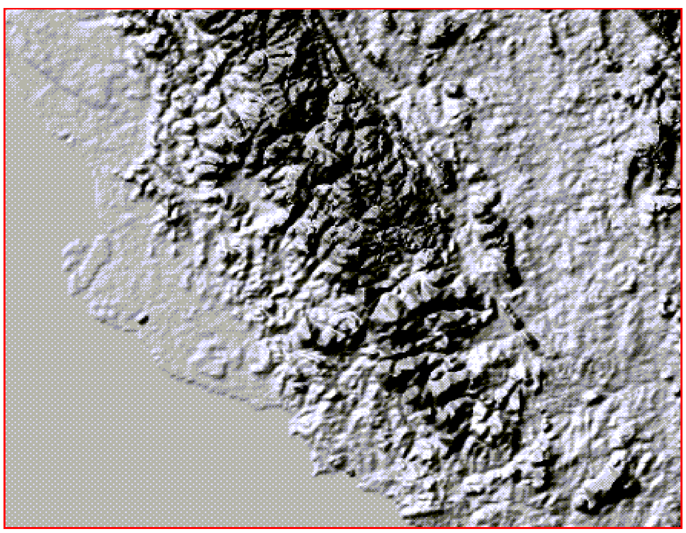

Figure 6: Improvement DTM

6. CHANGES OF FORMAT AND STRUCTURE

Owing to the additional information collected, format and structure of the existing system should be changed and make available to meet these needs. Later, the amendments should emphasize on (a) Procedures in Survey and Mapping Director General Secular, (b) Output structure of the data collection, (c) Adjustment methodology and data processing, (d) Existing NDCDB Structure , and (e) Existing eCadastre application.

6.1 Procedures in Survey and Mapping Director General Secular

Procedures and guidelines should be amended to accommodate these needs in the field which emphases the following:

a) Start station should have an orthometric height;
b) To record the height of instrument and height of prism;
c) To read vertical angle instead of zenith;
d) To record temperature readings;
e) To calibrate the Total Station;
f) To calibrate the Tribrach;
g) To amend the weights used in LSA;
h) To use Differential Field Test (DFT) for the observed vertical angle;
i) The limit in the dispute of height value;
j) The method of taking offsets and offset features; and
k) The display of the products.

6.2 Output structure of the data collection

The format and structure of the existing output for data collection by using Total Station and GNSS should also be transferred. The amendments involved include the following:

a) File FBK For 16 ASCII
b) File TPS For 16 ASCII
c) COO File for 16 ASCII
d) TPO File for 16 ASCII
e) POT File for GNSS observations

6.3 Adjustment methodology and data processing

Processing and data adjustment methodology adopted should also be reviewed and amended as appropriate. Among the aspects that should be addressed are as follows:

a) Data adjustments in Adjustment LSA
b) Methodology Fixed Points for Adjustment LSA
c) Value Adjustment Weights for LSA

6.4 Existing NDCDB Structure

The existing NDCDB structure should be revamped to accommodate the height orthometric to development the 3D-NDCDB. Elevation information should be stored in the NDCDB STONE layer.

6.5 Existing eCadastre application

The existing eCadastre applications and Oracle databases should be reviewed and revamped to meet these requirements. Among those are:

a) eTSM (Title Survey Module);
b) eCRM (Cadastral Reference Marks);
c) SUM (Virtual Survey System);
d) EQC (Quality Assurance);
e) ESSM (Strata/Stratum/Marine);
f) DRP (Digital Raster Plan);
g) eGLMS (GIS Layer Management System); and
h) Oracle Database.

7. CONCLUSIONS

The purpose of this paper is to give a brief understanding and an overview of cadastre systems in Malaysia. The empirical study proposed a suitable solution, where possibility of embedding Three-dimensional National Digital Cadastral Database (3D-NDCDB) into the existing National Digital Cadastral Database management model, i.e. introduce height value for each cadastral boundary mark. The important aspect here is the measuring instruments such as Total Station and the GNSS used. They must be in good condition. Good calibration of devices is very important and must be complied with the corrections in data measurements.

According to Tan, Liat Choon (2013), the development of a multipurpose cadastre information system requires the contribution of many different departments to execute the fundamental components of the system. Both the governmental and private institutions have to be involved concurrently to integrate all items of the new system. The implementation of each component is carried out by specific institutions at national, regional, and local level. The new system could aim for support land planning, land administration, land taxation, and cadastre. For dissemination purposes, even hyperlinks from the cadastre or its spatial indexes to the data files of land-use planning authorities may be sufficient. However, the multiplicity of organisational and legal relations stresses the importance of structure information and in making information more widely accessible. Efficient data exchange must be focussed on data modelling, standardisation and an appropriate use of the common spatial reference framework.

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BIOGRAPHICAL NOTES

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