FEASIBILITY TO DEVELOP THREE DIMENSIONAL NATIONAL DIGITAL CADASTRE DATABASE USING REMOTE SENSING DATA

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A thesis submitted in fulfilment of the
requirements for the award of the degree of
Master of Science (Geomatic Engineering)

Faculty of Geoinformation and Real Estate
Universiti Teknologi Malaysia

JUNE 2016

Specially dedicated to Mak and Abah
(Rapiah binti Mat Sam dan Mohamad bin Yaakob)

Ini kali keduakan dan doakan pasti ada untuk kali ketiga….

To my beloved husband
(Mohd Jeffri bin Nurul Huda)

You mean everything to me

To 3Sitiku
Siti Aisyah, Siti Balqis dan Siti Hajjar

Mesti lebih terbaik dari ibu yer….

ACKNOWLEDGEMENT

Alhamdulillah. First and foremost, I wish to express my heartiest appreciation to my main thesis supervisor, Assoc. Prof. Kamaludin bin Mohd Omar and my Co-Supervisor Dr. Abdullah Hisam bin Omar for support, enthusiasm and the valuable guidance throughout the period of supervision, the Department of Geoinformation staffs, members for the support and Department of Survey and Mapping Malaysia (DSMM) for providing valuable data used in this study. Special thanks to DSMM State of Johor in assisting me to complete my study. Also for all the invaluable excellent guidance, technical support, encouragement, concern and critics advices and friendship.

Last but surely not least, I am deeply grateful to my lovely family members especially to my beloved husband Mohd Jeffri bin Nurul Huda for his unlimited patience, loving inspiration most enthusiastic support during the whole tenure of my research. My sincere appreciation to my parents Mohamad bin Yaakob and Rapiah binti Mat Sam for their encouragement, advice and who taught me the value of hard work.

ABSTRACT

National Digital Cadastre Database (NDCDB) contains 40 million boundary marks that are based on Geocentric Datum of Malaysia (GDM 2000) for Peninsular Malaysia and Federal Territories of Malaysia. Currently, the NDCDB is a two-dimensional (2D) planimetric coordinate database without elevation information. Enhancement of the existing NDCDB is needed in order to suit the current situation and demands for real world modelling. One way to deal with this situation is to upgrade the current database to a three dimensional (3D) Cadastre Database that provide 3D information about land. The objectives of this research are: i) to investigate and to examine the feasibility of developing the 3D NDCDB; ii) to develop a new method for providing height information in cadastre survey and iii) to evaluate the accuracy of height information generated from Light Detection and Ranging (LiDAR), Interferometric Synthetic Aperture Radar (IFSAR) and cadastre survey. Development of the 3D NDCDB involves the introduction of height information into the existing cadastre boundary marks (CBMs), extracted from various data sources such as LiDAR for urban areas in Mukim Setapak, Kuala Lumpur, IFSAR for rural areas in Mukim Simpang Kiri, Batu Pahat, Johor and from field observation in cadastre survey using the trigonometric levelling technique for new CBMs at lot 48330, Bandar Johor Bahru. The trigonometric levelling technique is used to determine the elevation difference between two stations by the triangle formula. The evaluation of accuracy of height information generated from existing CBMS is based on Root Mean Square Error (RMSE) and the accuracy of new CBMs is evaluated with reference to the accumulated error from Cadastre Reference Mark to CBMs. The results showed that the accuracy of vertical RMSE of generated height information for existing CBMs is ±11cm for LiDAR and suitable to be introduced into 3D NDCDB for urban areas. For rural area, the height accuracy is ±0.7m for IFSAR. The accuracy derived for new CBMs is ±8cm and it shows that trigonometric levelling technique is suitable to produce height information into new CBMs with several improvement in field data observation practices.

ABSTRAK

Pangkalan data digital kadaster kebangsaan (NDCDB) mengandungi 40 juta batu sempadan yang merujuk kepada Datum Geosentrik Malaysia bagi Semenanjung Malaysia dan Wilayah-wilayah Persekutuan di Malaysia. Pada masa kini, maklumat ini disimpan di dalam pangkalan data koordinat planimetrik dua dimensi (2D) dan tanpa maklumat ketinggian. Penambahbaikan kepada NDCDB sedia ada diperlukan bagi memenuhi keperluan masa kini dan permintaan kepada model sebenar rupa bumi. Salah satu cara bagi menangani keadaan ini adalah dengan menambahbaik pangkalan data sedia ada kepada pangkalan data tiga dimensi (3D) kadaster untuk menyediakan maklumat tanah 3D. Objektif kajian ini adalah: i) untuk menyiasat dan mengkaji kesesuaian membangunkan NDCDB 3D; ii) untuk membangunkan satu kaedah baru untuk menjana maklumat ketinggian dalam pengukuran kadaster dan iii) untuk menilai ketepatan maklumat ketinggian yang dijana daripada pengesanan cahaya dan jarak (LiDAR), citra radar sintetik interferometri (IFSAR) dan pengukuran kadaster. Pembangunan NDCDB 3D melibatkan pengenalan maklumat ketinggian ke dalam tanda sempadan kadaster sedia ada (CBMs) dan ianya diterbitkan daripada pelbagai sumber data seperti LiDAR bagi kawasan bandar di Mukim Setapak, Kuala Lumpur, IFSAR bagi kawasan luar bandar di Mukim Simpang Kiri, Batu Pahat, Johor dan juga pengukuran kadaster di lapangan menggunakan kaedah ukur aras trigonometri bagi CBMs baru di lot 48330, Bandar Johor Bahru. Kaedah ukur aras trigonometri digunakan untuk menentukan perbezaan ketinggian di antara dua stesen menggunakan formula segitiga. Penilaian ketepatan menegak bagi maklumat ketinggian dihasilkan dari CBMs sedia ada adalah berdasarkan ralat purata punca kuasa dua (RMSE) dan ketepatan CBMs baru dinilai dengan merujuk kepada ralat terkumpul daripada Tanda Rujukan Kadaster ke CBMs. Keputusan menunjukkan ketepatan menegak RMSE dihasilkan oleh maklumat ketinggian untuk CBMs sedia ada adalah ±11cm bagi LiDAR dan sesuai diperkenalkan ke dalam NDCDB 3D bagi kawasan bandar. Untuk kawasan luar bandar, ketepatan menegak adalah ±0.7m bagi IFSAR. Ketepatan yang diperolehi bagi CBMs baru adalah ±8cm dan ia menunjukkan bahawa kaedah ukur aras trigonometri adalah sesuai digunakan bagi menghasilkan maklumat ketinggian CBMs baru dengan beberapa penambahbaikan dalam amalan cerapan data lapangan.

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ARS	Active Remote Sensing
BT68	Borneo Triangulation 1968
CALS	Computer Assisted Land Survey System
CBMs	Cadastre Boundary Marks
CCI	Cadastre Control Infrastructure
CCS	Coordinated Cadastre System
CDIS	Cadastre Data Integrity System
CDMS	Cadastre Data Management System
CP	Certified Plan
CRM	Cadastre Reference Mark
DCDB	Digital Cadastre Database
DFB	Digital Field Book
DRP	Digital Raster Plan
DSMM	Department of Surveying and Mapping Malaysia
DTM	Digital Terrain Model
eTSM	Electronic Total Station
FC	Field Communicators
FIG	International Federation of Surveyors
GDM2000	Geocentric Datum of Malaysia
GDQA	Geospatial Data Quality Assessment
GeoNAMES	Geographical Names
GIS	Geographical Information System
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GRAVSOFT	Geodetic Gravity Field Modelling Programs
GRS 80	Geodetic Reference System 1980
IFSAR	Interferometric Synthetic Aperture Radar

IMU	Inertial Measurement Units
IT	Information Technology
ITRF	International Terrestrial Reference Frame
LiDAR	Light Detection and Ranging
LIS	Land Information Systems
MASS	Malaysian Active *GPS* System
MPC	Multipurpose Cadastre
MPGN2000	Malaysian Primary Geodetic Network 2000
MRT 48	Malayan Revised *Triangulation*
MS 1759	Feature and Attribute Codes
MSL	Mean Sea Level
MyGEOID	Malaysian Geoid Model
MyRTKnet	Malaysian Real-Time Kinematic GNSS Network
NDCDB	National Digital Cadastre Database
PMGVD	Peninsular Malaysia Geodetic Vertical Datum
PLN	Precise Levelling Network
RMSE	Root Mean Square Error
RRR	Rights, Restrictions and Responsibilities
RTK	Real-Time Kinematic
SDI	Spatial Data Infrastructure
SPID	Image Document Management System
TIN	Triangulated Irregular Network
TON	Tidal Observation Network
UPI	Unique Parcel Identifier
3 D	Three-Dimensional
2 D	Two-Dimensional
VSS	Virtual Survey System
VRS	Virtual Reference Station
WGS 84	World Geodetic System 1984

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CHAPTER 1

INTRODUCTION

1.1 General Background

Over the past decades, Malaysian cadastre systems have endured drastic changes from various aspects intechnically, operationally, structurally and institutionally. The inspirations for these changes are important due to the necessity for the increasing service provision and competence and the huge demand of the client (e.g. agencies, private sector, user) and governments. There are two (2) main organizations controlling the cadastre system in Malaysia. The cadastre survey is the responsibility of the Department of Surveying and Mapping Malaysia (DSMM) as a federal agency to further modernize the cadastre system in Peninsular Malaysia. In addition, DSMM is also accountable for providing, producing and managing the spatial element comprising the surveying and mapping of the cadastre land parcels (Zulkifli et al., 2013). Secondly, the Land Office is responsible for non-spatial component in Land Registration System.

The cadastre survey has been practiced in two-dimensional (2D) and currently it provides crucial land and property information such as ownerships of the land parcel for most areas of the nation (Hassan, et al., 2008). Nowadays, the existing 2D information is unable to accommodate more advanced circumstances for example in urban areas. The best solution to deal with this situation is to enhance the existing cadastre system from two-dimensional (2D) to three-dimensional (3D). This means, with the support of the current technologies, Malaysia could initiate the 3D Cadastre system since it has good 2D Cadastre framework.

In this regard, under this project, DSMM has generated a homogeneous and accurate National Digital Cadastre Database (NDCDB) by capturing the survey accurate information of all land parcels on new geocentric datum concept nation, except for Sabah and Sarawak. The NDCDB is the vital element in the development of large-scale geospatial database in Malaysia and it also a base-map for the development of Multipurpose Cadastre (MPC) in Malaysia (Taib, 2012).

In recent years, cadastre systems have been influenced by the introduction of the web and Cadastre 2014 that have deeply impacted on the geoinformation stage through the development of the MPC concept (Shamsul Abdul Majid, 2000). The concept is defined as:

‘A framework that supports continuous, readily available and comprehensive land-related information at the parcel level (Panel on a Multipurpose Cadastre, 1980)’.

A Multipurpose Cadastre (MPC) is designed to record, store and provides not only land records information but also a wide variety of parcel-object related information using large scale base map (Jamil et al., 2014). MPC also has a capability to support spatially enabled government, private sectors and society and to expand computer support in the process of visualization, organization and management of useful land information (Taib, 2012).

The MPC database is established by optimizing various geospatial datasets to generate large-scale Geographical Information Systems (GIS) base maps. Numerous countries in the Asia Pacific have taken steps to transform their cadastre system to become MPC. Singapore is transforming their cadastre system into full 3D Cadastre in order to overcome their dense on-ground and underground development. Republic of Korea also has embarked on a pilot project for 3D Cadastre mapping in Seoul and the development of the 3D National Spatial Data Infrastructure (NSDI) policy (Dong et al. (2012). Malaysia is presently undertaking a pilot project in one of its Federal Territories, Putrajaya to provide informative insight on the future direction in implementing nationwide MPC and new cadastre management in the country. The fundamental of survey accurate MPC is mainly survey-accurate NDCDB which is populated, adjusted through a process of quality review at every level of its establishment. As explained by Taib (2012), the survey accurate MPC is one of the spatially enabled system is used to integrate a system of land information contains various information like survey-accurate cadastre, man-made features, topography surface and accurate reference framework. Figure 1.1 shows the MPC components provide the enhancement of delivery system to the public as well as realization of connected government.

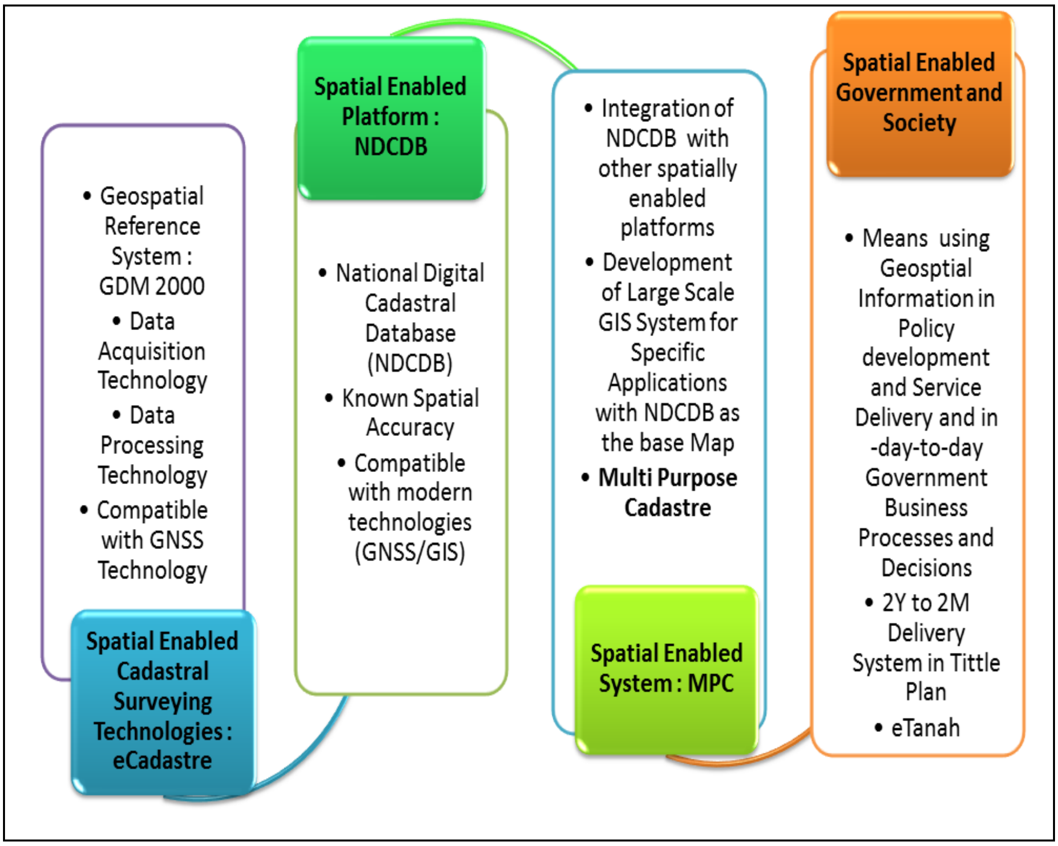

Figure 1.1: The Enhancement of Delivery System to the Public (Taib, 2012).

In order to implement MPC in Malaysia, the main necessity required to capture which is MPC core dataset that illustrated in Figure 1.2. One of the vital components is survey-accurate NDCDB. As quoted by Taib (2012), *the manisfesto of survey accurate NDCDB is to maintain a homogeneous spatial accuracy of cadastre boundary coordinates to better than 5 centimeters in urban area and better than 10 centimeters in rural area or less developed area*. This demands the establishment of a survey accurate database at the national level for GIS consumers and also a wide variety issues related to the formation of this database crucial to be addressed (Choon and Seng, 2014).

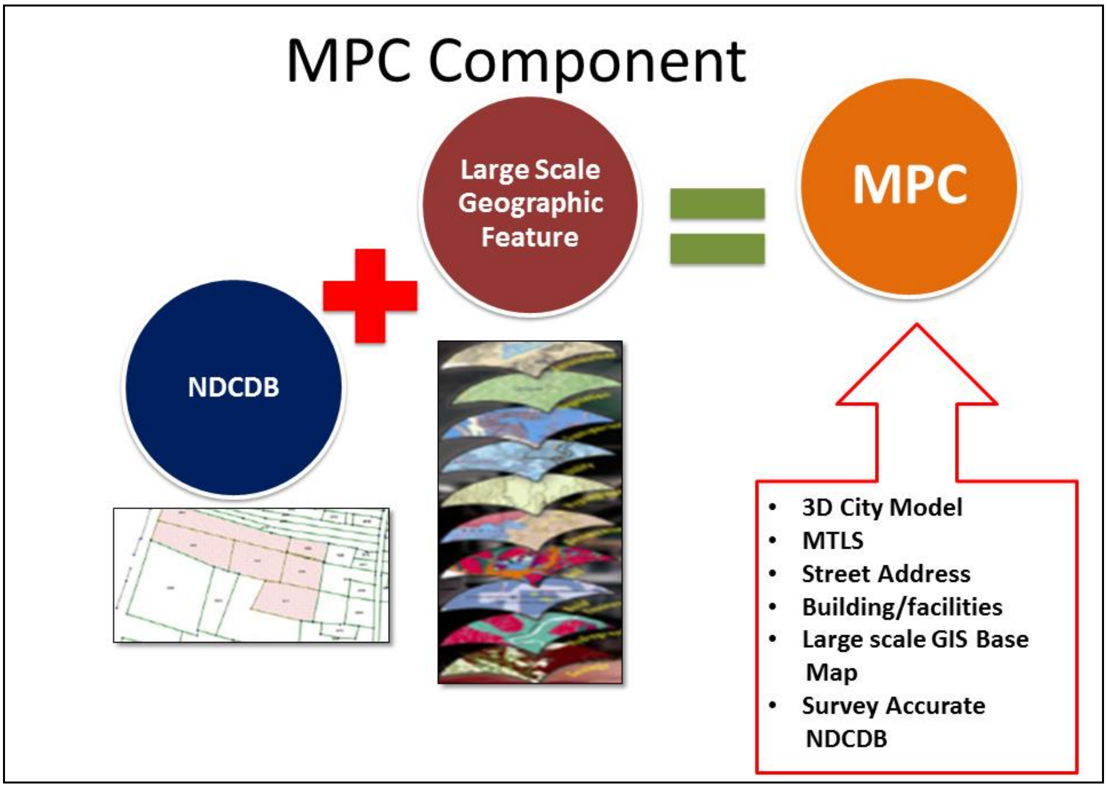

Figure 1.2: MPC Components (Taib, 2012)

1.2 Research Motivation

Over the years, cadastre systems have inclined to acquire a reputation for reliability, well defined prosedure and 'cast iron' guarantees of rights in land parcel (Ragunah, 2006). Tremendous pressure on scarce land because of increasing population and consequently infrastructure development activities on, above and below the land surface are main driving forces for emergence of 3D Cadastre.

With increasing demand for a competent land use above and below the surface is inspiring cadastre and land management systems to move from traditional 2D systems toward 3D ones. A main concern in realizing the 3D Cadastre vision is the development of competent approaches for the attachment of the 3D to the existing 2D systems (Filin et al., 2005).

According to the report of Cadastre 2014, feature cadastres will show the complete legal situations of land, including public rights and restrictions (Kaufmann and Steudler, 1998). All these rights, restrictions and responsibilities related to land are often overlapping, therefore, current 2D cadastre systems have revealed limitations in certain 3D circumstances (Doner and Biyik, 2007). From the perspective of scientific and technological, the principal challenge in developing a 3D Cadastre lies in collecting, processing and managing the 3D data.

One of the main principles of the development of cadastre system is the fully 3D land parcel information surface. Previous study that has been executed by Stoter and Gorte (2003), to integrate of 2D data and elevation information in cadastre land parcel. Moreover, Doner and Biyik (2007) stated that, in 3D Cadastre, surface models are used to generate elevation surfaces of cadastre land parcels.

Nowadays, with the recent technologies in surveying such as active remote sensing and Global Positioning System (GPS) enable to be collected the 3D data with high accuracy. Although it is possible to collect 3D data by means of several techniques, it entails huge amount of time and budget to resurvey all the data which is already available today (Doner and Biyik, 2007). In terms of the observational time is too lengthy, making it a slow, labour-intensive, painstaking and costly operation, resurveying of 2D parcels may not be practical to locate them in 3D space and elevation information.

Currently with the emerge of advanced aerial mapping techniques such as Airborne Light Detection and Ranging (LiDAR) and Interferometric Synthetic Aperture Radar (IFSAR) data are now widely used for a number of applications, notably those requiring a Digital Terrain Model (DTM). Thus, it can be more appropriate to integrate LiDAR or IFSAR data to the current 2D data. Filin et al., (2005), Souza and Amorim, (2012) and Morska et al.,(2013) have performed previous study on airborne laser technology like LiDAR to 3D Cadastre. In this regard LiDAR that offers direct acquisition of dense and accurate 3D data for integrating airborne laser scanning data and existing 2D cadastre system**.**

The primary motivation of this research is to explore and examine a feasibility development of 3D NDCDB with several data sources. The addition elevation data into cadastre boundary marks (CBMs) in the NDCDB would produce a 3D NDCDB. The 3D NDCDB is a mixture of the land parcel boundary and elevation information into cadastre boundary marks in order to acquire a parcel surface and it can be integrated with 3D objects like tunnel, cables, pipelines and etc. Moreover, this can be one way of the solutions to determine parcels in 3D space with integration of 2D Cadastre data and elevation information.

1.3 Problem Statement

DSMM has initiated the modernization programme of the cadastre survey system in stages in line with the advancement of current technologies. eCadastre is the latest venture in empowering the digital cadastre database of DSMM in order to accelerate the delivery system for land title surveys. It is implemented with new fully GIS-ready database, namely the NDCDB. At present, NDCDB is contains 40 million CBMs based on Geocentric Datum of Malaysia 2000 (GDM 2000) for Peninsular Malaysia and Federal Territories of Malaysia (Taib, 2012). Recently, NDCDB is adopted a database of two-dimensional, where the information is stored in two-dimensional planimetric coordinate (North (N), East (E)) without vertical information (Height (H)). However, in the future, 2D information may no longer capable to serve the community owing to the high demands for enriching information from the NDCDB, notably in more complex high-density developments in urban areas.

According to Hassan et al. (2008), an increasing requirement in using space on, above or below the ground surface for constructions of real objects notably in big cities areas (Hassan et al., 2008). The mission of Cadastre 2014 as recommended by the FIG Commission 7, stated that in the future the cadastre system must not depend on 2D mapping (Choon and Seng, 2013). Enhancement of existing NDCDB is required to suit the current circumstances. One way to deal with this situation is by having more 2D Cadastre database which include the 3D information about land information to NDCDB by using a wide variety of data sources. This research is carried out to create height information to 2D land parcels and generate the terrain surface in 3D space. However, the delimitation this study only concentrates on vertical element. The problem is divided to two (2) main categories which are as follows:

i. Generated height information for existing cadastre boundary marks (CBMs) by using several data sources, i.e. LiDAR in urban area and IFSAR in rural area;

    a) The stage of processing LiDAR and IFSAR data using the ESRI 3D software package; and
    b) The accuracy of height information derived from LiDAR and IFSAR.

ii. The determination of height information for new cadastre boundary marks (CBMs). The detailed studies should be conducted for;

    a) Field data acquisition using Digital Field Book (DFB).
    b) Adjustment and calculation of observed data;
    c) Changes of format and structure of the existing system;
    d) 3D NDCDB with height information of each boundary mark, Digital Terrain Model (DTM) and 3D Certificated Plan (CP); and
    e) The estimated accuracy of height information from the new cadastre survey.

1.4 Research Objective

The aim of this study is to investigate feasibilities development of the 3D NDCDB with various data sources and assessment the quality of the generated elevation.

The specific objectives of this research include:

i. To investigate and to examine the feasibility of developing the 3D NDCDB;

ii. To develop a new method for generating height information in cadastre survey; and

iii. To evaluate the accuracy of height information generated from LiDAR, IFSAR and a new cadastre survey.

1.5 Significance of Research

One of the vital principles in the development of a 3D Cadastre system is to provide land with elevation data. Combination of elevation information and 2D land parcel enables to locate the cadastre land parcel in 3D space. Currently, NDCDB is two-dimensional in nature. As mentioned earlier, it does not contain elevation information within the land parcel area. Solution towards 3D Cadastre is to study possible solutions in adding a 3D component (N, E, H) in the current situation. This enhancement will be used as a platform to suit with the Malaysian Cadastre System. For the future, the NDCDB is capable of storing, visualizing and manipulating accurate legal records of 3D data.

Elevation information contributes to inform decision making and impact a wide range of vital activities including mapping and charting, flood risk determination, transportation, flood mitigation, land use and others. The 3D NDCDB is a paradigm shift for modern cadastre system and a step towards the MPC concept. It is not only enhancing the government frameworks but also providing more realistic and useful information for all levels generally (Ajibah, 2014).

The need for height information for approaching urban problems has grown rapidly. The requirements comprise design and inspection of utilities such as water mains, tunnels, sewer systems, bridges, railroads, roads and power lines and also for city planning and development purposes (Mathias, 2001). In the past, the determination of height information would usually suffice with contour lines. Currently, the demands with respect to accuracy are far beyond this point. The latest remote sensing methods have emerged which are capable to react to these demands. This situation shall trigger a good basis for the integration of height information from the remote sensing data and 2D cadastre data.

The significances of this study include:

i. Enhancing NDCDB;

ii. The elevation of land surface is used for computation of land area and volume more efficiently;

iii. Guideline to authorities to form a strategy toward 3D NDCDB;

iv. The height information derived can expand the application of NDCDB especially for urban area; and

v. In line with recent technology development, such as Multipurpose Cadastre, Cadastre 2014 and Spatially Enable Government.

1.6 Organization of Thesis

In this research, there are total of five (5) chapters, each overview plays a vital part in describing the development of 3D NDCDB. The description of each chapter has designated as follows:

Chapter 1 provides a general overview of the research. It contains the description of the background study and clarify the general idea of this study. This chapter comprises background of study, research motivation, problem statement, aims and research objectives, research question and significance of this research.

Chapter 2 reviews the literature on the basic understanding of the research before conducting the study. In this chapter, explanation an overview on cadastre, 3D Cadastre, Malaysian Cadastre System, height reference system, height determination techniques, remote sensing technologies and 3D surface model. In a literature review, materials that are relevant to the research are obtained from various sources and have been used as a reference to enhance understanding of the theories in order to complete this study.

Chapter 3 introduces the flow of work of this study and it is shown in the form of flow chart. This chapter will involves technical processes to create the 3D NDCDB. All techniques used are discussed in this chapter. In performing these processes the researcher has to use ESRI's 3D software package. There are five (5) main processes in the methodology, which are data acquisition, data processing, data analysis, data validation and result and analysis.

Chapter 4 shows the results obtained from this study. This chapter discusses on accuracy assessment of each result for LiDAR, IFSAR data and new cadastre survey. Meanwhile, defines the analysis in the form of graphical presentation. Finally, the results will be analyzed and been discussed.

Chapter 5 concludes the finding of this study. Recommendations are given to discuss the different point of view might be useful for further development of the study.

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