KERTAS KERJA 20

Tajuk : Rapid Large Scale Hybrid Mapping Using UAV And MLTS For Multi-Purpose Cadastre

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Keywords: Multipurpose Cadastre, Mobile Terrestrial Laser Scanning (MTLS), Unmanned Aerial vehicle (UAV)-based LiDAR, Network-RTK

Summary

Geospatial data capturing for mapping has gone through many stages of modern development since the introduction of the first theodolite. To date, various new and innovative techniques have been introduced into the science of survey and mapping. JUPEM in particular has vast experience in using aerial and satellite imagery in photogrammetry for the production of large and medium scale maps. This technique is well suited for the production of normal line map for set purposes. However, updating based on the same technique is slow and expensive.

With the current era of digital revolution, maps and geospatial information can be disseminated quickly in the information super highway to users requiring up–to-date geospatial information. The requirement of up-to-date map is never so urgent in areas with rapid developments where a standard revision of every 3 years is a no-no. With the rapid advancement in aerial acquisition technology a hybrid solution can be seen as an innovative viable option. This paper looks into the possibility of using an UAV-based in combination with MTLS-based mapping system as the available off-the-shelf solution for rapid Multi-Purpose large scale Cadastre mapping. This paper describes the implementation of MPC in Putrajaya. It highlighted some of the issues and challenges encountered and the possibility of introducing new elements in its recommendation for way forward.

1. Introduction

JUPEM has initiated the implementation of Multipurpose Cadastre (MPC) for Malaysia under the 10th Malaysia Development Plan in 2011 with the total reengineering of the survey workflow for Cadastral surveying. A pilot project was conducted in the Federal Territory (FT) of Putrajaya to better understand the complexity of implementing MPC concept for Malaysia. MPC can be defined as integrated land information system containing legal, physical, and cultural information in a common and accurate reference framework. Web-based GIS and mapping functionality across the web nowadays have encouraged the MPC concept to be adopted to facilitate the increasing demands for comprehensive cadastral data for multiple purposes. The concept introduces the National Digital Cadastral Database (NDCDB) as the main reference map layer which contains all information related to boundaries of surveyed land parcels. NDCDB covers the whole of Peninsular Malaysia utilizing the new Geocentric Datum for Malaysia 2000 (GDM2000). It has been adjusted with respect to cadastral control infrastructure (CCI) developed using JUPEM's network-RTK or MyRTKnet to provide a homogenous and seamless cadastral network for the entire Peninsular Malaysia and the Federal Territory of Labuan.

The main source of large-scale geographical features for urban areas is based on the Mobile Terrestrial Laser Scanning (MTLS) survey that is referenced to GDM2000 and Mean Sea Level (MSL) height datum. The same data from MLTS is also used to develop 3D city models using google sketch-up. The technique however has its limitation when it comes to dealing with tall multiple storeys building where the equipment is not able to capture data for higher than several storeys. The available system could only reach distance to a range of approximately 250 m with the use of high grade MTLS. Thus a new UAV-based LiDAR technique is seen as a viable solution in addition to MLTS and cheaper in the long run for urban large scale mapping to fulfill MPC requirement. The MPC project, in essence created a database with layers consisting of NDCDB, 2D geographical features, 3D city model, utility data, and street addresses. At the moment MPC is a stand-alone system where all information is located in a single database rather than in several databases linked using SOA technology. The online application known as OWA has only basic functionality with restricted public access.

2. MPC Concept And Implementation For Malaysia

Cadastre can mean many things depending on definition used. By general definition, Cadastre covers both land administration and cadastral surveying. In Malaysia, Land administration is under the jurisdiction of the states government while cadastral survey is under the jurisdiction of JUPEM which is a Federal entity. The initiative by JUPEM on MPC only focuses on the cadastral and other spatial information.

The Putrajaya pilot project will provide the informative insight on the development of such system and could provide valuable insight on the future direction in implementing nationwide MPC and new cadastral management in Malaysia. MPC can provide vital geospatial dataset to users for navigation purposes, emergency management, property market management, urban planning and land development. However such information requires regular updating and real-time access to make it useful. The project included an online application that allows Government and public access. This is seen as an important tool to gauge public response and to receive feedbacks. This will allow JUPEM to assess public acceptance to formulate the necessary policy for data sharing and data transaction. The MPC development covers seven phases as shown in Table 1.

Development Phases	Details
1. NDCDB	Refinement and enhancement of existing NDCDB.
2. Large Scale Geospatial Data Acquisition using MLTS	MTLS is used to capture large-scale spatial features such building, road, utility, vegetation and others features during the survey.
3. Large Scale GIS Base Map	Local Geospatial Data Centre dataset that consists of large scale topographic map and other GIS layer.
4. MPC Module	Application modules for integration of multiple data sources, validation of MPC database and updating new spatial features.
5. 3D-SDI	Applying data fusion method to generate 3D city model and 3D SDI using available large scale MPC database.
6. MPC Database	MPC database will consists of various geospatial datasets with MS ISO compliance for both data and metadata. The development of MPC database includes the following processes: i) data format translation ii) data structure migration iii) data editing iv) data checking v) data validation
7. Online Web Access (OWA)	OWA provides access to spatial data as well as mapping and spatial analysis over the Internet. OWA has the following functions: i. Features Location; ii. Spatial Reference (example road map); iii. Context information -what data are currently relevant for

	specific circumstances; iv. Ability to analyze context; v. GIS standard; and vi. Ability to access context information continuously.

Table 1: Scope of Pilot Study

The reference framework for MPC is the survey accurate National Digital Cadastral Database (NDCDB) established using MyRTKNet of geodetic standards utilizing the new Geocentric Datum for Malaysia 2000 (GDM2000). NDCDB covers the entire country and contains information from cadastral survey jobs related to boundaries of land parcels. NDCDB has been adjusted with respect to cadastral control infrastructure developed using JUPEM's Global Positioning System (GPS) MyRTKnet to provide a homogenous and seamless cadastral network for the entire Peninsular Malaysia and the Federal Territory of Labuan. The main source of large-scale geographical features for urban areas is based on the Mobile Terrestrial Laser Scanning (MLTS) survey which is also referenced to GDM2000 and Mean Sea Level (MSL) height datum. The existing large scale basemaps extracted from State NDCDB and MyGDI State Geospatial Data Centre (SGDC) formed part of the fundamental components of MPC Data Infrastructure. The other important components are the large scale basemap layers such as 3-D City Model, Street Addresses, Building/Facilities and LiDAR Images. The project, ultimately, created an MPC database together with an Online Web Access prototype designed to facilitate a spatially enabled system that integrate land information system which contains survey accurate cadastre, topography, man-made features and cultural (e.g., land use, demographics) information in a common and accurate reference framework through a portal site on the World Wide Web. The *Service Oriented Architecture* (SOA) concept is also being studied to ensure seamless Cadastral business process.

3. MPC Database

MPC database is the heart of the whole system. It contains all the information required for users to use, analyze and to make informed decisions. The MPC Database is categorized into Demarcation, Built Environment, Geology, Hydrography, Hypsography, Transportation; Soil, Vegetation, Utility, General, high resolution satellite image, Special Use (LIDAR), Land Valuation, Asset/Facilities information, 3D city model, DTM, and 3D terrestrial point cloud. Demarcation data is essentially NDCDB and is the reference layer of MPC database for both topology checking and validating. MPC Database adopted the Malaysian Standard for Feature and Attribute Coding

Catalogue which is MS1759 for all its feature attributes. In the context of a 3D city model, the main objects modelled are ground, buildings, transportation network, bodies of water, city furniture, electric power lines, and vegetation objects. At addition 3D SDI for FT Putrajaya duplicates all 12 data categories with the additional of 3D city model data categories. All geospatial dataset are seamless and complied with Malaysian Standards, namely:

- Geographic Information/Geomatics – Feature and Attribute Codes (MS1759);
- MyGDI Metadata Standard (MMS);
- National Geonames Database;
- JUPEM Unique Parcel Identifier (UPI) and administrative code; and
- JUPEM Colour Code and Symbol.

All the dataset is based on the new Geodetic Datum (GDM2000). Coordinate transformation to Cassini and RSO Geocentric and vice versa is executed using certified transformation paramater acquired from JUPEM. Pre determined Cassini Geocentric and RSO Geocentric Coordinate ground proofing were carried out using GPS survey. The large scale geospatial datasets obtained from MLTS were verified to ascertain the accuracy in both horizontal and vertical. The study concluded that accuracy for dataset is as shown in Table 2.

Dataset	**Accuracy**
New_NDCDB	± 5cm (Horizontal) at 1σ
Point Clouds from MTLS	±16 cm (Horizontal) depending on satellite condition at 1σ
Point Clouds Vertical Accuracy from MTLS base on NGDV	±40 cm: 1σ
Geospatial Features from Ortophoto (over MTLS)	N=±2.48m, E=±5.85m
3D Model Spatial Accuracy	± 18cm

Table 2: Accuracy Achievable

4. Large Scale Geospatial Data Acquisition For 3d City Modelling

Data capturing using MLTS is seen as a viable way of obtaining large scale data within a short time for 3D City modeling. A DynaScan system (Figure 1) comprising of scanners, GNSS units, Inertial Measurement Unit (IMU) and processing software is used for the job. The accuracies of DynaScan MTLS system at 95% confidence level (1σ) are ±5cm in the horizontal and ±7cm in the vertical. The 3D point cloud obtained from the MTLS is used to produce geospatial information comprising of building footprint, road, utility (lamp post, fire hydrant, electrical post and else), lake, tree and other features. The project area is shown in Figure 2. Figure 3 described the adopted methodology for MPC MTLS data collection.

Figure 1: MTLS Dual Laser DynaScan 3 system

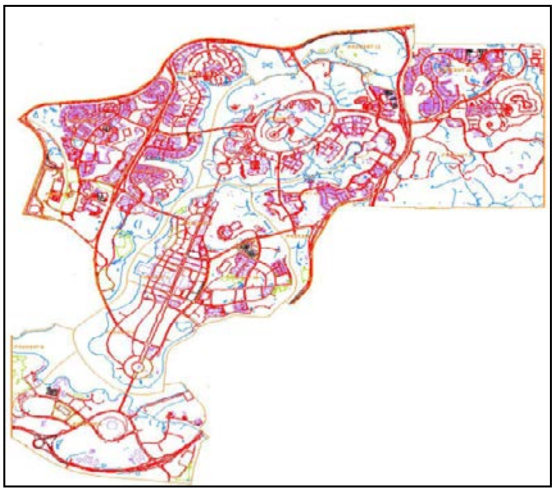


Figure 2 : FT Putrajaya MTLS Pilot Study Area

The work process for data collection covers 5 phases namely: i) Project Preparation; ii) Mission Planning; iii) Field Survey Planning; iv) Processing of Point Clouds; and v) Digitization from processed 3D Point Clouds.

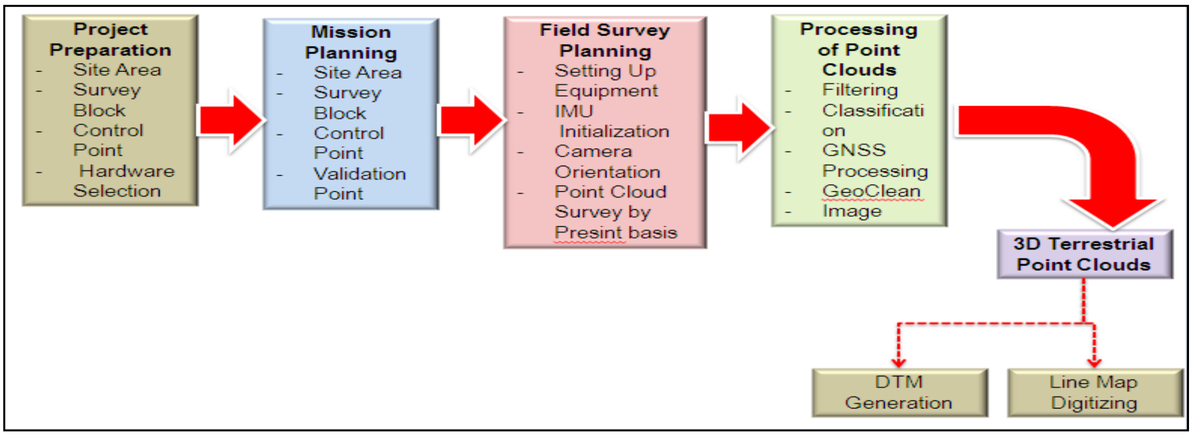


Figure 3: Adopted Methodology for MTLS Data Collection

The point clouds data obtained in GDM2000 were transformed using the in-house Geodetic Datum Transformation System (MTRANS) Version 4.1 software and projected to Geocentric Cassini (GDM2000) coordinates system. The height system is based on the National Geodetic Vertical Datum (NGVD) and orthometric height value is obtained by converting the ellipsoidal height to Mean Sea Level (MSL) height using MyGeoid and local levelling bench marks.

Work flow on the processing methodology for the collected MTLS data is shown in Figure 4.

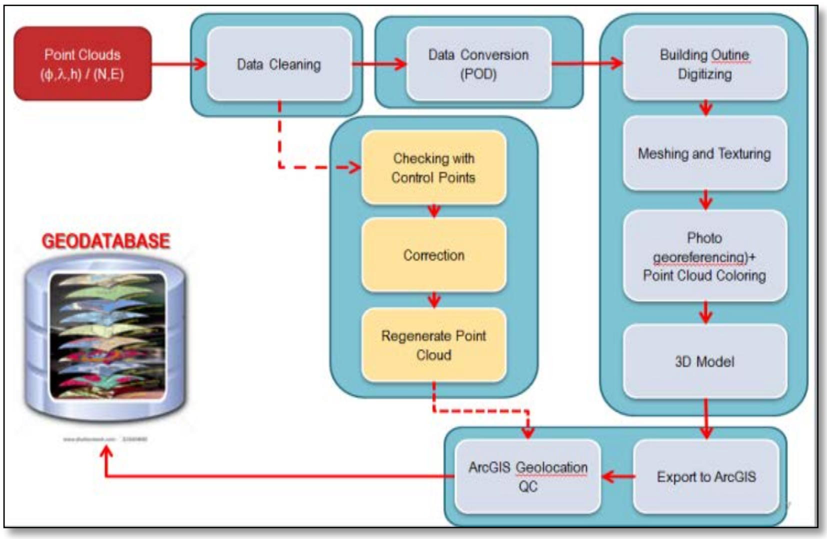
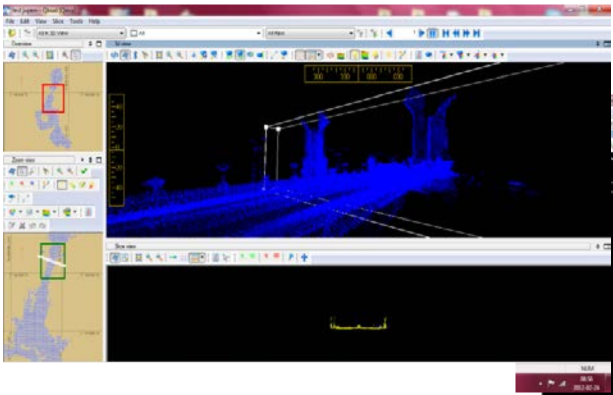
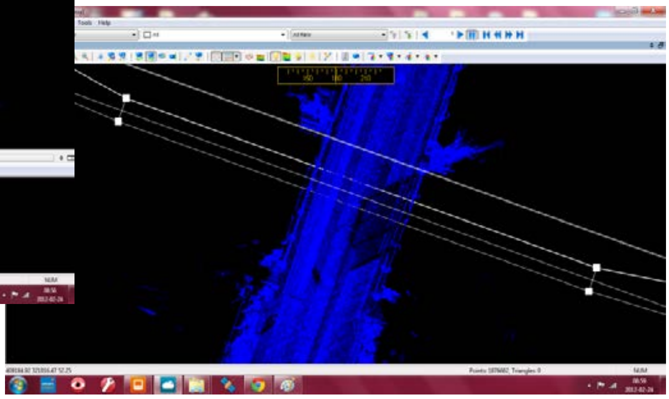


Figure 4: MTLS data processing methodology

Figure 5 and 6 shows the 3D point cloud of one of the features collected (Sri Gemilang Bridge in Putrajaya) at different viewing angle.



1.1.1.1.1.1.1 *Figure 5: 3D point cloud of bridge observed from eye*



1.1.1.1.1.1.2 *Figure 6: 3D point cloud of bridge observed from top*

5. 3d City Model For Federal Territory Putrajaya

The degree of information or resolution depicted in the building model can be determined based on the level of Detail or LoD. For the pilot project, 3D Model for FT Putrajaya is manually build using Google Sketchup and then exported to ArcGIS Map. This was then integrated to database and set as a globe project in ArcGIS Server. This project could be recalled via a client PC through ArcGIS Explorer Desktop. The Level of Details 2 (LoD2) is used to depict 3D building in the housing estates. Residential area in Presint 14 is used as a pilot area for LoD 2 digitizing. Level of Detail 3 (LoD3) is used to depict main government buildings along the main boulevard in Putrajaya (Figure 7). A LoD4 model has also been developed for a building at Putrajaya Central.

Figure 7: 3D Model FT Putrajaya

The 3D City model visualization for FT Putrajaya integrates image textures in the rendering process. This process generates virtual reality of the real world for Putrajaya. Sketch-Up application software and ArcGIS Desktop Explorer software were used to drape the related image to 3D city model as shown in Figure 7 and 8. Attribute entry were carried out based on the available information obtained (Figure 9). Data fusion from multiple geospatial datasets contains attributes information enriches the 3D city model as well.

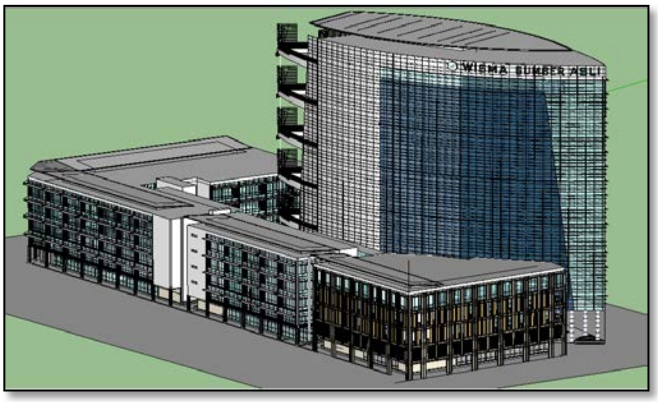


Figure 8: Integration of Image Texture to 3D city model

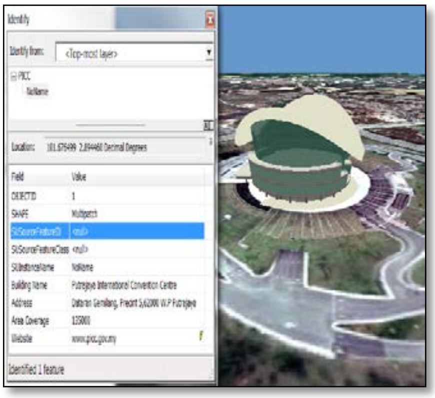


Figure 9: Object Attribution

6. Online Web Access (Owa)

The OWA is developed to allow public access and distribution of geospatial information to worldwide users using web GIS. Internet users are able to access GIS applications from their browsers without purchasing proprietary GIS software. The application has been developed using ArcGIS Server platfrom accessed via ArcGIS Explorer Desktop or ArcGlobe with service oriented architecture (SOA) functionality. In addition, the 3D Online Web Access provides access to the 3D datasets and possible SOA services MPC uses ArcGIS Desktop Explorer for 3D viewing. The software is available to download from the Online Web Access page. All public viewing of 3D Models will be through the software (Figure 13). Users are required to have logins to view the 3D city models.

7. Issues And Challenges Encountered Through Out The Pilot Study

Some of the immediate issues and challenges encountered during the implementation of the pilot project and their solutions are as follows:

ISSUES / CHALLENGES	SOLUTIONS
The exiting data have multiple format and different parameter as there was no standardization. Conversion was necessary to make all data obtained seamless. In actual fact, some of the data is similar in different department but there is no data sharing among department. This caused the obtaining of duplicate data in certain area.	Single custodian to handle all the data available within JUPEM. The custodian will be in charge of maintaining the standardization of the data. All data will maintain the current MS1759 standards. Furthermore, with single custodian, duplicate data can be minimized and be integrated into a single database. It is recommended the usage of either shapefiles (*.shp) or geodatabase (*.gdb) as the standard format.
The data collected is huge. In terms of vertical value, vertical exaggeration is required to be able to analyze the vertical value.	Higher end graphic cards with GPU functionality can minimize the strain in displaying large scale data. More detail can be shown without the need of exaggeration.
The scanning capability on MTLS is limited to 150m. A proper survey scale unit is required for denser point clouds.	Higher end survey-capable laser scanners are available in the market. They provide further distance (250m) with better accuracy.
The current system is limited to a single local RTK station.	The system should be upgraded and able to use the network-RTK system of the Department.
The server requires a separate GPU to process demanding graphical data. The current setup is sufficient. But this would not be adequate if the doers require multiple layers especially CPU intensive layers such as Point Clouds or LiDAR data.	Additional GPU unit for the server can increase the speed of the graphical data transfer and processing. For huge data viewing from server, a high end GPU is required.
The server is able to output up to 1 gigabit of Ethernet connection but if the switch is of a lower bit speed the data transfer would be limited by the switch output capabilities. 1 gigabit speed is required to transfer graphic intensive data such as multipatch data or 3D city buildings	A commercial switch with higher speed is required to maintain the speed of data transfer. Cat 6 cabling will help maintain the speed and minimize speed drop.
MS1759 does not cover all features. Multiple feature name and attributes has to be created to fit new feature name.	Newer feature code listing and colour coding is required. Further discussion should be made to identify new feature codes with the relevant Authority.

ISSUES / CHALLENGES	SOLUTIONS
A proper security protocol is required for users' login to safeguard confidential data. The current system only allows for Web Mapping Service (WMS) which is similar to Google Maps.	Security firewall is required to protect all data and application.

However, one of the main issues which require highlighting is the availability of data for frequent updating of spatial information. This issue is much more pressing in area where there is high development such as in the capital city of Kuala Lumpur. The main source of information such as aerial photo and satellite imagery are sometimes not available or inundated with cloud cover. This can be overcome with LiDAR data from satellite or terrestrial mapping using MTLS. The use of MTLS however is insufficient to completely fulfil the requirement to build a city model. It lacks the capability to capture data from top of buildings and the higher side of buildings in order to completely digitize a building.

8. Possibility Of Incorporating Uav-Based Mapping Data Capturing Technique Into The System

Figure 14: Swissdrone (Courtesy of Leica Geosystem)

A rotary type UAV-based image acquisition system, be it utilizing normal digital imagery or LiDAR is seen as the viable method of updating for MPC. It has the capability to be quickly deployed on site in a very short notice. The UAV would comprise of camera angled vertically or at 45 degree enabling it to collect data of sides of building. The system could cover a wide area within 50 km radius and can be operated automatically with manual override.

The major obstacle in obtaining the system would be the initial financial investment of procuring the system. However, expected regular use of the system would break even the investment within a short time with huge benefit in the form of up-to-date data with low wastage.

However this hasn't taken into account the requirement of DCA when operating UAV based platform. Certain country would require line of side when operating UAV. In this case that should not be a problem where rotary platform is concerned since the speed involved is much slower when compared to a fixed wing platform.

9. The Way Forward For MPC

For MPC to be relevant, public assessment and feedback should be sought from stakeholders such as government agencies, private sector and the public. Limited feedback from stakeholders indicates that MPC could play an important role in promoting spatially enabled societies with the implementation of SOA. Data sharing would be more practical when data is kept within the data custodian and shared through SOA.

There is also an urgent need to develop a program for the production of large scale base-map in urban areas to support MPC. A survey grade MTLS system together with UAV-based LiDAR system is seen as a viable solution in 3D point cloud data acquisition to ensure higher level of accuracy and resolution of the acquired 3D features. To help with data acquisition, the scope of existing cadastral survey for JUPEM should be enlarged to include building foot-print, drain, fire-hydrant, access road, etc., and the features are to be updated into MPC Database. At the same time, the MPC Database needs to be continuously updated, maintained and finally integrated with other databases such as JUPEM's Strata and Marine database.

In addition, for JUPEM to be relevant this hybrid solution would allow JUPEM to be at the forefront in providing up-to-date geo-information and to show to the nation decision makers JUPEM's capability in providing up-to-date geospatial imageries. However, before that could materialized JUPEM must firstly have a proper organization structural set-up. A well trained specialized mobile unit capable of being deployed at short notice anywhere in the country can be seen as one of the options for the department to consider.

JUPEM is set to move forward with the introduction of MPC to other major cities. Priority should be given for the implementation of MPC in Cities like Kuala Lumpur in Peninsular Malaysia and WP Labuan in phases. Since most of the build-up areas in cities consist of high-rise buildings, constructing city model at LOD3 would be a challenge without the availability of data from UAV-based system. The acquisition of UAV-based LiDAR should be seen as a serious option for large scale data acquisition. With the successful implementation of MPC in urban area, implementation for semi-urban and rural areas with reduced resolution could then follow suit.

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Acknowledgment

I personally acknowledge Sr Hasan Jamil, Sr Dr. Teng Chee Hua and Sr Nur Zurairah Abdul Halim for their contributions either directly or indirectly in the writing of this article.