3D Cadastre in Singapore

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Key words: Cadastre System, 3D Cadastre, Cadastral Survey, 3D GIS, GIS, Singapore

SUMMARY

Property rights have always been shown in 2D with the surface parcel being the fundamental representation of ownership. Complex 3D situations, interlocking properties, multi-levelled train station, underground rock caverns are all immediate but unresolved challenges for us in Singapore. Volumetric parcels such as strata subdivision, subterranean and airspace parcels are currently recorded and represented in 2D plans. Is the 2D system adequate to delineate complex multi-levelled development that we see in Singapore today? Is the 2D information recorded sufficient for stakeholders?

As the custodian of authoritative cadastral boundaries in Singapore, there is a great responsibility on Singapore Land Authority to uphold the integrity of the cadastre. Ultimately, the public is depending on SLA to provide accurate and reliable cadastral survey records.

The objective of this paper is to describe the current state of the cadastre system in Singapore and the need for implementing a 3D cadastre system. It will also discuss the real world scenarios related to volumetric ownership, examine the driver for 3D cadastre and outline the plan going forward.

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1. INTRODUCTION

As in 2010, the land area of Singapore is approximately 712.4 square kilometres with a total population of about 5 million. It is one of the most densely populated countries in the world (estimated population density of over 7000 per square kilometre). With an area of about 700 square kilometres, we have very limited land to meet the needs of our people and our growing economy. Hence, the government is very serious in optimising land use to ensure sustainable growth for the nation.

The Singapore Land Authority (SLA) was formed in June 2001 from a merger of the former Land Office, Singapore Land Registry, Land Survey Department and Land Systems Support Unit. SLA's mission is to optimise land resources for the economic and social development of Singapore. We endeavour to balance the economic development needs and social needs with:

- ensuring the best use of State (government) land and buildings,
- providing an effective and reliable land management system, including the administration of cadastral survey and the issuance of property titles, and
- enabling the full use of land information for better land management and creation of new business opportunities.

SLA provides a one-stop service for all transactions that were previously provided by the four land departments. Broad range of these transactions is available over the Internet so that our customer is able to access the services with ease and convenience. It also provides land information that is authoritative, comprehensive and easily accessible.

Cadastre system and cadastral information play significant role towards economic and social development in Singapore through a stable and reliable property registration system. Traditionally, the system serves as the foundation for property transactions and securing the legal status of property boundaries and this role will continue to be significant. Today, with the advancement of GIS (Geographical Information System) technology and the introduction of seamless GIS layer containing all property parcels in Singapore, the cadastral survey information has become the most critical land base information to support development and planning work. This cadastral GIS layer is made available to both public agencies and general public through various online channels. Many government agencies heavily depend on this layer for their planning and operation work to serve businesses, communities and individuals.

Our challenges in Cadastre System are to be able to stay relevant and progress fast enough to support the industry and general public. Hence, SLA has been constantly looking for ways to further improve the cadastre and one of the main thrusts moving forward is 3D Cadastre.

This paper aims to provide an overview of the cadastre system in Singapore, describe the current cadastral survey practices, discuss the real world scenarios related to volumetric ownership, examine the driver for 3D cadastre and outline the plan going forward.

2. CURRENT CADASTRE SYSTEM

Singapore adopts the Torrens System of conveyane and title registration. Its Cadastre System is made up of the "Register" and the "Map". In SLA, Cadastre System is maintained by 2 departments; the "Register" is under the purview of Land Title Registry Division and the "Map" is under the purview of "Land Survey Division". Under the Land Titles Act (Chapter 157) (in short LTA), the Registrar of Titles is responsible for the registration of titles while the Boundaries and Survey Maps Act (Chapter 25) (in short BSMA) grant power to Chief Surveyor for the conduct of cadastral survey. The overview of cadastre system supported by 3 databases is illustrated in Figure 1. The detail of the databases will be discussed in the following sections.

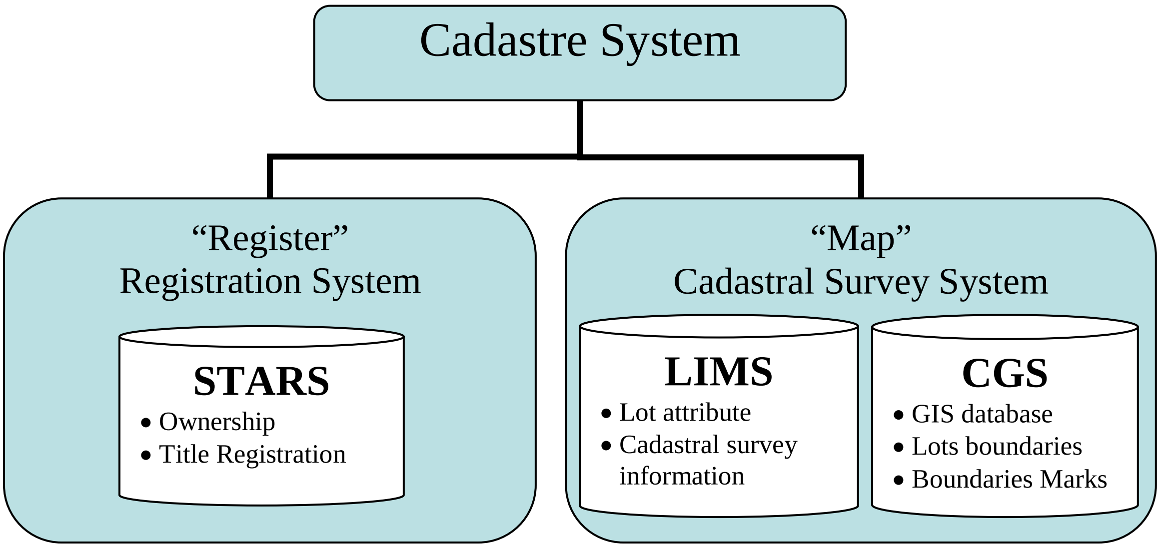

Figure 1. Overview of Cadastre System in Singapore

2.1 Existing Cadastral Survey System

Over the last 18 years, we have embarked on various initiatives to modernise our cadastral survey system. These improvements are needed for the system to stay relevant. In 1992, the former Land Survey Department started the establishment of a new geodetic control network known as the Integrated Survey Network (ISN) with Global Positioning System (GPS) technique. In 2004, after 12 years of various changes, the new cadastral survey system based on the Coordinated Cadastre concept was implemented. (Khoo, 2005 and Andreasson, 2006) We have fully converted all our land lot boundary coordinates to the new SVY21 coordinate system which allow the usage of Differential GPS. In 2005, Electronic Submission of cadastral survey jobs and paperless job processing was introduced. In 2006, SLA implemented an active CORS (Continuously Operating Reference Station) network known as the Singapore Satellite Positioning Reference Network (or SiReNT) to support the cadastral survey work (Soh *et al.*, 2006). Further information on Singapore's cadastral survey system is available in SLA website (http://www.sla.gov.sg).

The Cadastral Survey System comprises of 2 databases. One is known as the Consolidated GIS System (CGS) which captures the geometry of land parcels (generally known as the Digital Cadastral Database, DCDB). Separately, another relational database (known as the Lot Information Management System, LIMS) is used to capture all cadastral survey attributes i.e. survey plan number, approval date etc. The CGS stores the authoritative legal boundaries of all land, airspace and subterranean in Singapore. Figure 2 shows the existing 2D GIS layers that overlay all the parcels which include the surface land lots, subterranean lots and airspace lots. The different types of property parcels will be discussed in the following section.

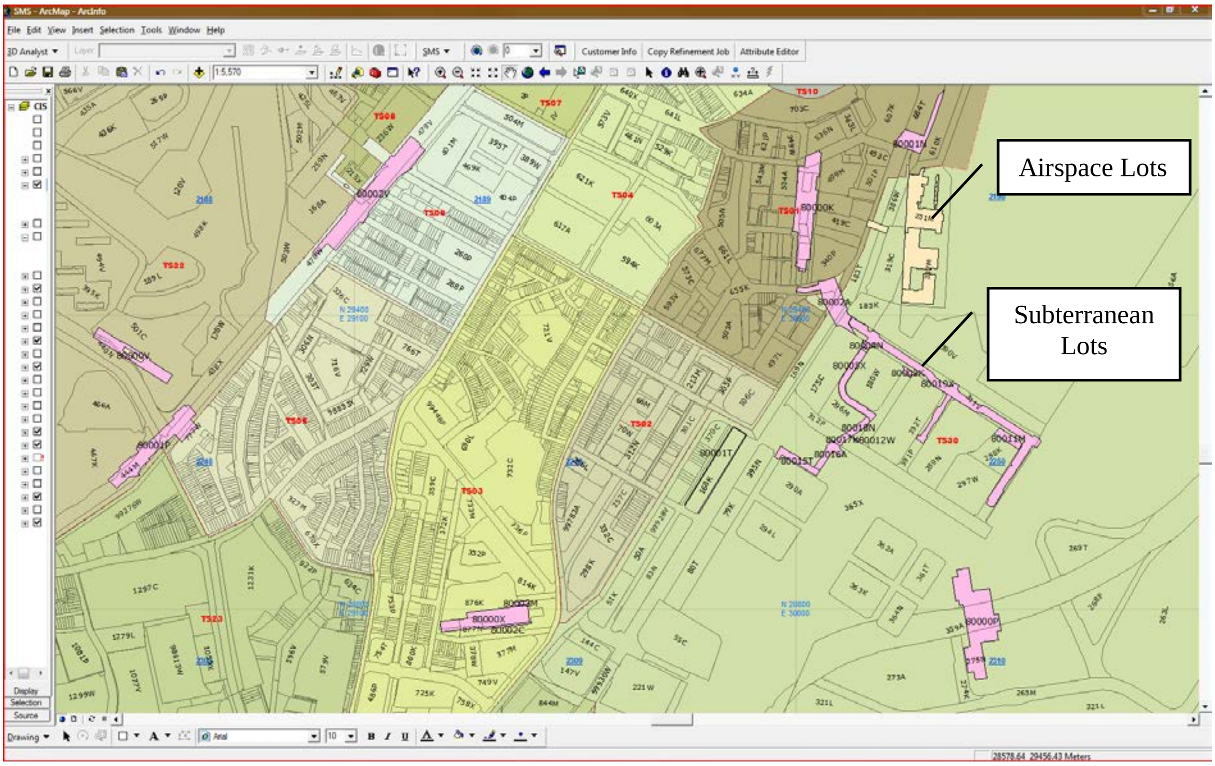

Figure 2. Existing 2D GIS layer capturing all land lots, airspace lots and subterranean lots in Singapore. (source: SLA)

2.2 Lots Types

The understanding of parcels differs with countries. A parcel is defined as a separated piece of land, to which a person (or persons) is (are) entitled with a real right, such as right of ownership. In Singapore, a property parcel is known as a "lot". A cadastral survey is carried out to determine the location, geometry and the size of a lot.

Under the Section 3A of Singapore's State Land Act (Chapter 314) on the "Mode of alienation" gives an implicit definition of "Land":

3A. *State lands which are alienated or otherwise disposed of, or in respect of which a lease or license to occupy is issued, under this Act may be alienated, leased or licensed —*

(a) as a parcel of the surface earth, all substances thereunder and so much of the column of airspace above the surface as is reasonably necessary for the use and enjoyment thereof;
(b) as a parcel of airspace or subterranean space, whether or not held apart from the surface of the earth; or
(c) only down to such depth below the surface earth as the President may by order direct."

The State Land Act provides the mode of land alienation in Singapore. While the Land Titles (Strata) Act (Chapter 158) provides for subdivision of building into strata units. Hence, these 2 legislations provide for 5 main types of lots in Singapore to define property ownership:

- land;
- airspace;
- subterranean;
- strata, and
- accessory lots.

2.2.1 Land Lots

A land lot refers to surface parcels which confer the owner with right from the centre of the earth all the way to the universe. The survey of land lot is carried out in 2 dimension projected to plane surface based on the SVY21 plane coordinate system. Each land lot is identified by a lot number and defined or located by plane coordinates of the boundary marks marking the extent of the lot. The technical detail regarding the conduct of cadastral survey for land lot is outlined in the Chief Surveyors Directive available via SLA website (SLA, 2011).

2.2.2 Airspace and Subterranean Lots

Airspace and subterranean lots were introduced in 1994 during the period of time when Singapore started to develop its subway system (known as the Mass Rapid Transit or MRT). Other than amending in the existing Acts (LTA, BSMA, and State Land Act) that "land" definition and modes of alienation include such airspace and subterranean, there was no new provision in any Act to legislate them.

Conceptually both types of lots are considered a form of land lot. They need to be defined by lower and upper limit as well as the horizontal boundaries. Figure 2 illustrate the concept of airspace and subterranean lots. Parcels above ground surface (surface parcel) are known as the airspace Lot and those below ground surface are referred to as subterranean Lots. The surface parcel (or land lot) still remain intact except that it is now has limited rights. In Figure 3, the extent of the rights for land lot is shaded and excludes the airspace and subterranean lots. The airspace and subterranean lots can be further subdivided into strata lots to facilitate the usage within the property.

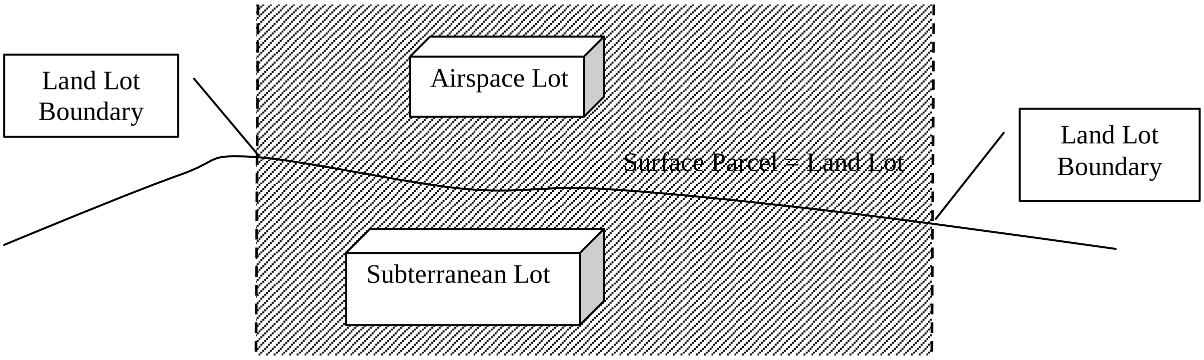

Figure 3. Concept of airspace and subterranean lots

In current cadastral survey practice, airspace and subterranean lots are defined by 2D coordinates having a height component referenced to a stratum. Multiple views depicting these lots are shown on the certified plan to enable better visualization of the lot under survey. Today, there are about 200 of such volumetric parcels and they are commonly adopted for above-ground and underground subway stations and commercial spaces.

2.2.3 Strata and Accessory Lots

The Land Titles (Strata) Act (Chapter 158) (in short LTSA) came into effect in 1967 to facilitate the subdivision of building or land into strata units (Christudason, 2003). The strata units are known as a "strata lot" which is a volumetric parcel defining a flat unit. Strata lots will always be a subset to a land lot or airspace/subterranean lot as the building . An accessory lot is a sub-unit (i.e. store room, toilet) of a strata unit which are made appurtenant to the relevant strata lot. These lots cannot be sold separately.

In the current survey practice, strata and accessory lots are not coordinated and the property boundary is with respect to the centre of the wall (an imaginary line) in most instances unless the entire wall is under the maintenance of the home owner or explicitly marked out on ground for cases where there is no physical structure. Currently, there are about 1.2 million strata lots in Singapore.

2.3 Survey Plan Types

There are 3 main types of survey plans used in our cadastral survey system:

- Registrar of Titles Plan (RT)
- Certified Plan (CP)
- Strata Certified Plan (CPST)

The RT plan captured the provisional boundaries of airspace, subterranean, reclaimed and foreshore lots. It is only allow for cases where the actual development takes time to complete and a plan showing provisional boundaries is required for property transactions. RT is usually prepared based on design dimensions and no actual survey on ground is needed. Its objective is to allow for transaction of the property before a cadastral survey is carried out.

The CP shows the final boundaries of land lots, airspace and subterranean lots. In land lot case, the boundaries of land lots are depicted by points having coordinates that define a polygon with an area. The plan also shows the history of lot mutation and type of mark used on the ground for demarcation.

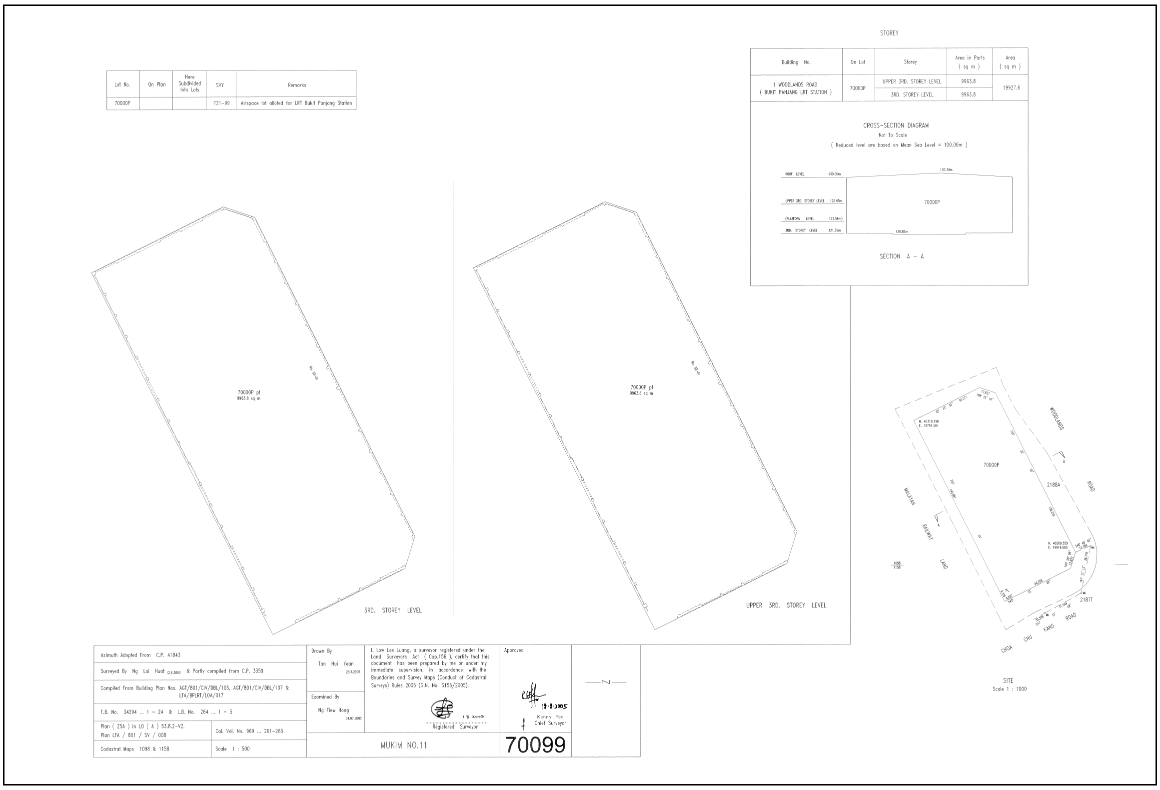

Figure 4. Certified Plan (CP) showing an airspace lot (source: SLA)

In the airspace and subterranean lots cases, the parcels are depicted in cross-section and plan views in the CP. Many cross-sectional views are needed to represent a complex parcel. In plan view, the coordinates of salient points for each level (or stratum) are recorded in the CP. The height of the lots is recorded as reduced level based on our national height datum. While in our GIS system, only the outermost outline of all levels of the parcel is captured. Hence, many boundary details are lost in vector format. See Figure 4 for a sample of CP showing an airspace lot.

A CPST display the final boundaries and the areas of strata and accessory lots. CPST contain different views of strata lots, including the site plan, the elevation sketch of building and the storey plan. The relative height of each strata unit with respect to ground and between each stratum is shown on the elevation sketch. The detailed demarcation of the strata and accessory lots are shown on the storey plan. This is a 2D + 1D system, where the height is not an absolute height base on national height datum. Figure 5 shows a sample of a CPST.

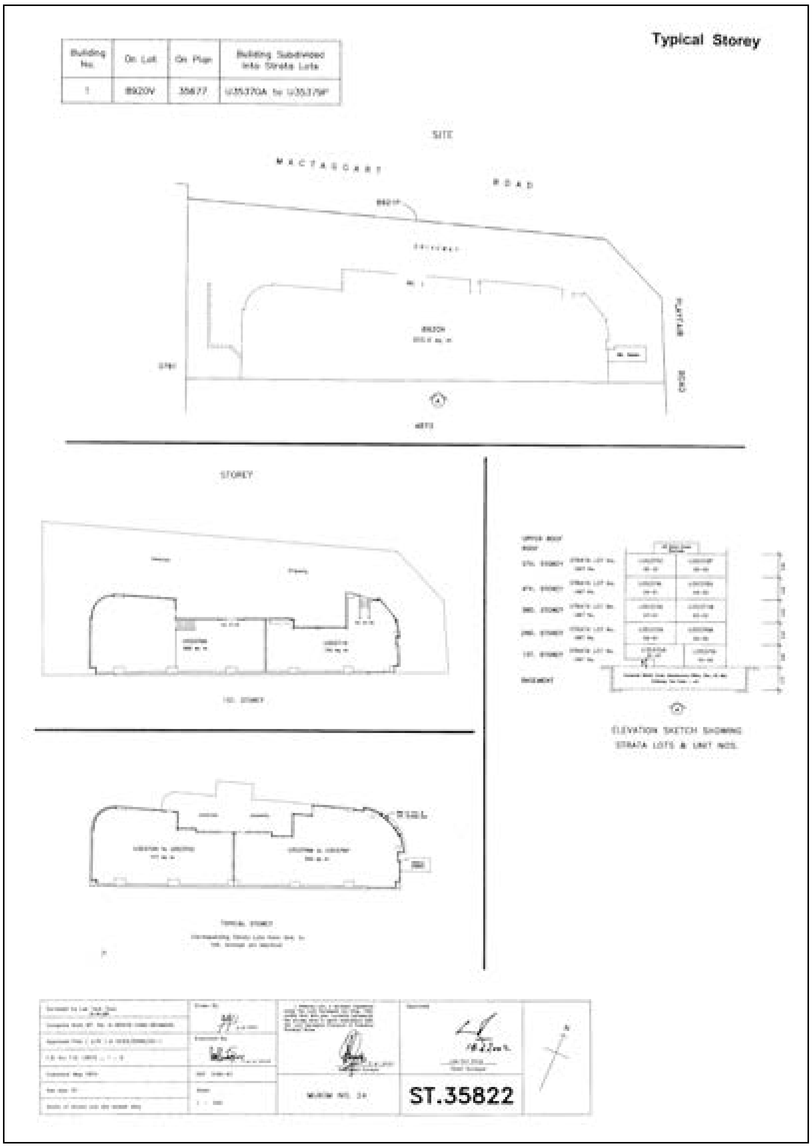

Figure 5. A sample of Strata Certified Plan (CPST) (source: SLA)

Broadly, the height information of a volumetric parcel is only recorded in survey plan which is in raster format. This information is not captured in our GIS system. It is evident that the existing cadastre system already allow for registration of volumetric parcels (airspace, subterranean and strata lots) but the height information is not appropriately recorded in our system to support spatial analysis and provide better visualisation. The existing requirement of measuring and capturing height of volumetric parcel is not rigorous as the objective is only to produce 2D survey plan.

3. NEED FOR 3D SYSTEM

Over the last thirty years, a 2D + 1D system would be more than sufficient to deal with simple property boundaries. A 2D planimetric survey plan is adequate and acceptable by the property owner. However, it is increasingly more challenging to deal with complex developments that are coming up ever so frequently. It is even more difficult for underground properties where the structure cannot be seen and very much depends on the accuracy of the cadastral plan that depicts such property boundaries. The underground development has intensified and has come very close to each other with many of them had to join and inter-lock with each other.

Figure 6. Complex and innovative development design (Source: The Interlace)

We are seeing more and more radical, complex and innovative development design in Singapore as the government progress towards transforming the city into an exciting place to *Live, Work and Play In (*http://www.ura.gov.sg). Figure 6 shows an example of a residential development which will be completed in 2014. The development adopts a new residential typology which breaks away from the standard isolated, vertical apartment towers of Singapore. There are thirty one apartment blocks, each standing at six-storeys tall and identical in length, are stacked in a hexagonal arrangement to form eight large open and permeable courtyards. This development will be strata subdivided. It is very challenging for surveyor to represent and depict the strata lots in the current 2D survey plan. Many details and overlaps may be disregarded in the 2D plan. Downstream, the property owner will have difficulty reading and interpreting the plan.

Figure 7. Integrated development linking commercial space to underground subway station (source: Archicentral)

Figure 7 shows an integrated development which has a basement connected to existing subway station. This is an example of subterranean development that comes close to each other. The development also was strata subdivided. Urban areas are increasingly opting for mixed development, constructing structures that belong to different owners on the same plot of land. The boundaries of these developments do not conform to straight walls or flat floors. The subterranean lots are interlocking with certain cases an escalator or a staircase which is slanting is used as the surface boundary for 2 lots. The integrity of boundaries, especially for complex developments is a persistent issue. The consequences of an unreliable cadastre would bring about uncertainty in property boundaries, which could lead to boundary disputes from inaccurate demarcation. Users of this information might be unwittingly misled causing accidents on space not properly identified.

With limited space, yet high demand for storage, Singapore government has been forced to look underground. We have started to develop the Jurong Rock Caverns which is located more than 100 meters below surface. When completed in 2014, it will be the first South-east Asia underground rock cavern for oil storage. This development is estimated to save about 60 hectares of surface land. Figure 8 shows the development of Jurong Rock Caverns. The land transport authority will expand rail and road network of Singapore and most of these development will be underground. Is the current cadastre system ready to support rapid development underground? We will be seeing more multiple layers of underground usage.

Figure 8. Underground rock cavern development (source: Jurong International)

In essence, our current cadastral survey system is inadequate to support the rapid property development in Singapore. The inability of our part to capture 3D cadastral boundaries accurately and rigorously could lead to:

- Ineffective development planning due to incomplete information of cadastral boundaries residing in our cadastral database;
- Re-work due to design errors by architects, engineers and planners who have based their calculation on the available 2D property boundaries parameters;
- Boundary disputes due to unknown or inaccurate boundaries; and
- Encroachment issues due to uncertainty in boundaries.

4. CONCLUDING REMARKS

In Singapore, the implementation of 3D Cadastre should be driven by needs from stakeholders and industry demand. It is important to indentify stakeholders from the government agencies, professional and property owners so that we can recognize impacts for each of the group. While the stakeholders may have a need, they may not aware of the benefits and realise the significance of 3D Cadastre. Hence, awareness creation and communication to engage stakeholders should starts as early as possible to convince and gain supports from them.

As the implementation of 3D Cadastre will impact many stakeholders, we prefer the conservative approach of breaking up the initiative into 3 major phases, with the success of each phase determining the progress to the next. The 3 phases proposed are:

- Phase 1 - Feasibility study and requirement gathering
- Phase 2 - Pilot Project

- Phase 3 – Actual Implementation which include data conversion, system development and changes to current process

Industry demand is another key driver for 3D cadastre in Singapore. The existing cadastral survey system is inadequate to support the rapid and dense development in our city state because it is not able to support the modelling of complex volumetric parcels that overlaps and interlock with each other. Professionals involved in civil and construction work such as architect and engineers has also started to use 3D design tools in their work. In productivity drive, our building and planning authorities have also started to require design submission in 3D BIM (Building Information Modelling) format. Hence, cadastral survey system and processes needs to stay relevant with the market to support its stakeholders.

Ultimately, 3D cadastre should be position as a critical mechanism to support the drive for optimisation of land use in Singapore. With this recognition, the 3D cadastre implementation will then be able to attract strong support from the government, professionals and general public.

In conclusion, SLA remains alert to the changing economic and social environment around us and recognise the importance of ensuring that our cadastre system are fully integrated into the business needs of our customers. We strive to stay aware of the developments, milestones and visions of our compatriots in other jurisdictions and to share ideas across boundaries with the hope of maintaining relevance, dynamism and innovation in our methods, approach and thinking.

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BIOGRAPHICAL NOTES

Victor Khoo is a Senior Principal Surveyor with the Land Survey Division of Singapore Land Authority (SLA). He received his Ph.D. and Master of Engineering from the Nanyang Technological University (NTU), Singapore and his Bachelor degree in Land Surveying from the University Technology of Malaysia (UTM). Victor is a Registered Surveyor; a professional surveyor registered under the purview of Singapore's Land Surveyors Act. He works in diverse geospatial related subjects that encompass the collection, management and dissemination of geospatial data. His specific areas of interest include Differential GPS, Cadastral Surveying and Spatial Data Infrastructure.

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