

Piloting 3D Cadastre in Singapore

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LIMITED LAND[•] UNLIMITED SPACE



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Introduction: Digitalization of Cadastral Survey in Singapore





Why transform to 3D cadastre in Singapore

- "Limited Land, Unlimited Space" Singapore Land Authority's (SLA) vision statement
 - Land scarcity
 - Vertical expansion for efficient use of space
- 2D cadastre is insufficient to represent complex development and related rights
 - Lack of clarity on the 3D geospatial relationship
 - Difficulties in reading and interpreting, the overall productivity is low
- Smart Nation development demands
 - 3D digital geo-info at unit-level for various use cases
- AEC industry transform to 3D in BIM
 - Cadastral survey system and process needs to catch up and support its stakeholders



3D cadastre development in other countries



- The FIG Best Practices 3D Cadastres (Oosterom (2018)) shows the research and development of 3D cadastre across the world
- In Vitoria, the University of Melbourne is collaborating with their government agency to develop 3D ePlan for 3D cadastres implementation by 2025 (Rajabifard et al.)
- Netherlands, how a 3D PDF was registered as legal document (Stoter et al.(2016))
- In Shenzhen, China, a 3D cadastral system has been developed to visualize 3D property formation (Ying et al. 2012)

What are we looking for - 3D digital strata survey submission

Current 2D strata survey submission workflow



Moving forward: 3D strata survey submission workflow



3D Strata Modelling



Auto-check against Regulatory Rules



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Key work areas for 3D strata



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- **1.<u>Objective</u>** Aims to figure out the workable workflow for as-built 3D digital strata survey using laser scanning and BIM technologies.
- 2.<u>Pilot site</u> A newly built public housing estate (HDB)
- Block 213C typical building and ready for strata survey
 - \circ 16 floors
 - o 130 housing units
 - lift cores, staircases, long corridors
 - $\circ~$ a childcare center at ground level







3. Workflow

1) Site survey – To establish horizontal and vertical ground control points based on SVY21 and SHD for Block 213C





2) Scanning on site

- Choose scanner
 - o terrestrial laser scanners (static scanners, mounted on the tripods)
 - o handheld laser scanners
 - o mobile laser scanners (mounted on a platform such as a trolley or backpack)

• Features to be scanned

- $\circ~$ exterior for the entire building
- \circ every individual unit
- \circ staircases
- \circ corridoors
- \circ aircon ledge





3) Point cloud registration

- Trimble X7 -->Trimble Business Centre (TBC) & Trimble Perspective
- Reigl VZ400 --> RiscanPro
- Multi-point clouds were aligned as one single, unified dataset using TBC
- Suggest to capture point clouds at same density
- Hign-end PC/Laptop is essential for point cloud processing
- The combined point cloud was exported to Autodesk Redcap format for next step



Point cloud of the Block 213C



4) 3D Modelling

- 3D Strata Model require -
 - Physical information building elements, such as walls, floors, ceilings etc
 - Legal information derives from the strata subdivision process, e.g, the boundaries of strata lots and common properties
- BIM can integrate physical model and legal model with cadastral information
- The physical model was created first based on the point cloud
- The legal model was then created based on physical model manually



Example of current 2D strata plan



3D Strata Model contains 3D physical structures and 3D legal space



1. Objective - Aims to figure out the BIM-based as-built 3D strata modelling methodologies.

2. Data source of physical model

- As-built BIM which derived from point cloud
 - Point cloud captured from site survey after the building reach to roof top
 - Opportunity to leverage on "Scan-to-BIM" technologies to create BIM (necessary physical building elements)





3. 3D Data Model and Modelling Methodologies

1) Adopt LADM as the fundation of cadastral database

- LADM has been used in many projects in different countries, including Singapore
- The existing data model implemented in the current CSMS in Singapore is based on LADM (2012) (Soon et al. 2016)

2) Localized IFC as the encoding format for 3D strata model

- IFC-SG is localized BIM standard based on the IFC 4 standard, using by AEC industry in Singapore
- SLA is working on the further development of IFC-SG to incorporate the 3D strata requirments





3) Mapping strata elements to IFC entities

- A BIM-based 3D strata model should include legal, physical and survey information
- The application of IFC standard in cadastre has been investigated a lot in different countries, e.g. "IfcSpace" and "IfcZone" entities are considered for modelling strata boundaries; "IfcGeographicElement" is considered for survey information etc
- SLA's pilot relies on the research outcomes from global experts

Strata Elements to be modelled	Mapping to existing entity (IFC4 Entities)	New Subtypes (IFC4 Userdefined Object Type)	IFC- SG_PropertySet (IFC4 Userdefined Property Set)	IFC4 (USERDEFINED) IFC- SG_PropertySet	IFC4 (USERDEFINED) IFC-SG PropertyName	Property Type	Sample Values
Strata Lot	ifcSpace	STRATALOT	SGPset_StrataLot		StrataLotNumber	Label	MK03-U017049L
Accessory	ifcSpace		ESSORVIOT SGPset Accessory		StrataLotArea	Area	120
Lot	псэрасе	ACCESSONTEOT	Jot		LotStatus	Label	Live
Common	ifcSpace		CDcot CommonD	CODest Chustel et	ParcelType	Label	Strata
Dronortu	licspace		supset_commone	SGPSet_StrataLot	ResidingOnLandLot	Label	MK03-01847M
Property	PERIT TOPERLY		SVYFileNumber	Label	0226-1985		
Void	псърасе	VOID	SGPset_Void		TypicalFloor	Boolean	TRUE
S AD Strate Floments to be manned to the IEC antities					UnitNumber	Label	05-02

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SL/3D Strata Elements to be mapped to the IFC entities

Mapping strata attributes to IFC-SG PropertySet ¹⁵

4) Modelling method

- Using Mass family in Revit to create 3D strata boundaries
- Modelled the typical floor and then replicated
- Associated the attributes to individual strata lot
- Exported the model from Revit to IFC-SG format



Final As-built 3D strata model of Block 213C



Using Mass family to create 3D strata boundary

Pilot 3 – Regulatory Validation and Visualization for 3D Strata Models

- **1.**<u>**Objective</u></u> Aims to develop 3D validation rules and process, and the 3D viewer, to support the 3D strata submission</u>**
- * At initiative requirements gathering stage





Pilot 3 – Regulatory Validation and Visualization for 3D Strata Models

1. Regulatory Validation

- Prevention of ambiguity in survey data is fundamental to safeguard the title registration.
- Validating cadastral data prior to it entering into a cadastral database is essential process.

Initial ideas

- 1) validation rules on the field data, e.g. control points, point cloud etc;
- 2) validation rules on the 3D geometries, e.g. 3D geometry must be closed and watertight, no gap and no overlap between two 3D ownership boundaries;
- 3) validation rules on the textual information, e.g. the lot number consistency between submitted data and SLA cadastral database records;
- 4) able to further develop/refine the validation rules even they have been implemented initiatly;
- 5) develop the intelegent validating process (e.g, automated valiation), to improve the productivity



Pilot 3 – Regulatory Validation and Visualization for 3D Strata Models

2.3D Visualization

- For further inspect the submission in a 3D environment and raise any query
- To develop an IFC-based 3D viewer with the functionalities of integrating BIM and the surrounding GIS data, viewing 2D plan and 3D model, checking the data quality, generate 2D plan from 3D model, as well as detect/verify encroachment etc.





1) Laser scanning is workable technology for as-built 3D digital strata survey

- 2) The BIM-based 3D strata modelling workflow based on physical BIM which derived from point cloud, including integrate the cadastral info into the 3D model in IFC format, have been demonstrated successfully
- 3) Modelling the typical floor and then duplicate it to the rest typical floors is practical to reduce modelling time and cost significantly
- 4) A code of practice for 3D strata survey submission and a more intelligent strata modelling tool should be developed for industry use







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