



## Piloting 3D Cadastre in Singapore

Defu WU, Kean Huat SOON, Victor KHOO

LIMITED LAND • UNLIMITED SPACE

RESTRICTED\NON-SENSITIVE

# Outline



## 1. Introduction

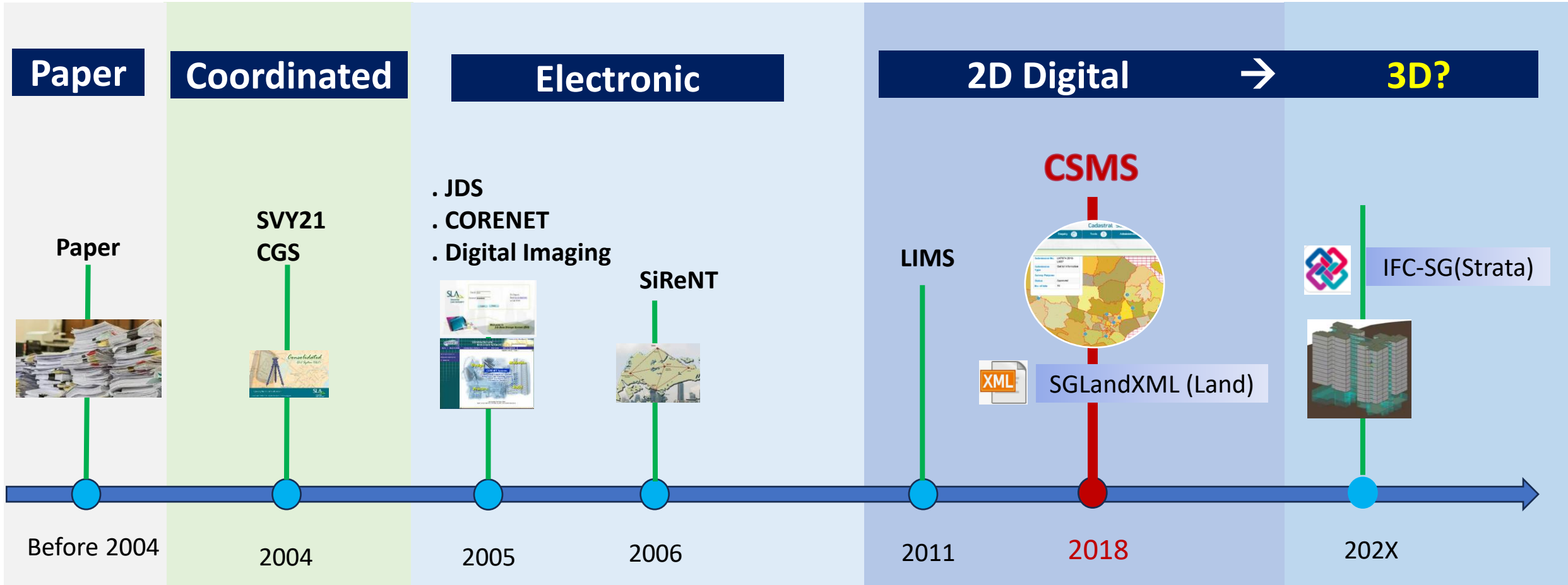
## 2. Key work areas for 3D strata development in Singapore

## 3. Pilots

- Pilot 1 – Digital 3D Strata Survey
- Pilot 2 – 3D Strata Modelling
- Pilot 3 – Regulatory Validation and Visualization for 3D Strata Models

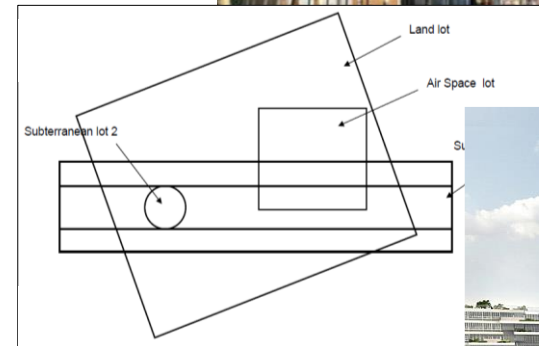
## 4. Concluding remarks

# Introduction: Digitalization of Cadastral Survey in Singapore

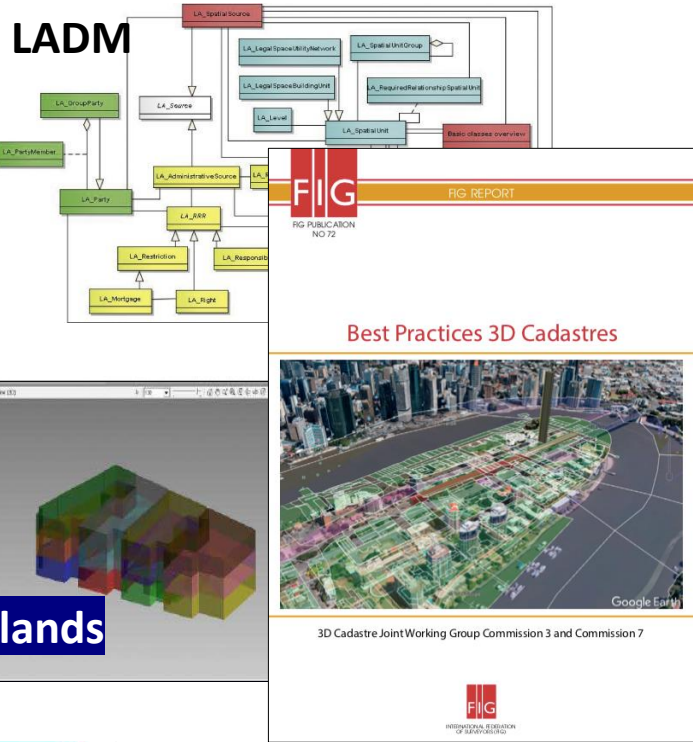


# Why transform to 3D cadastre in Singapore

- **“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

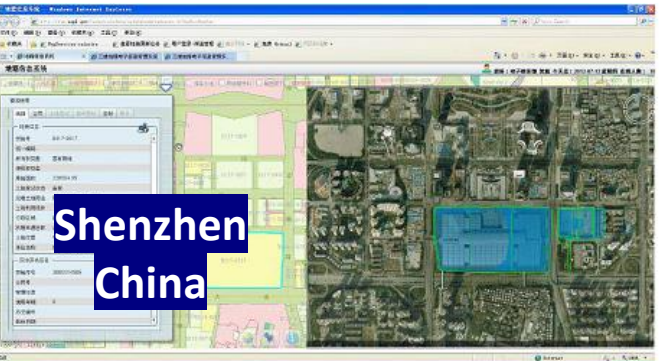


- The FIG Best Practices 3D Cadastres (Oosterom (2018)) shows the research and development of 3D cadastre across the world

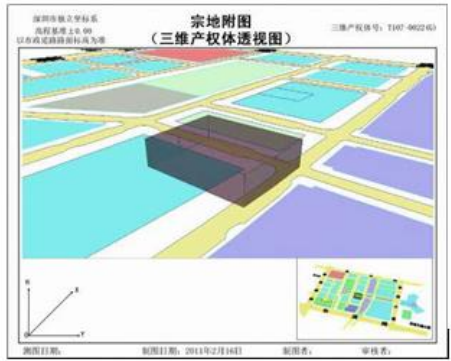


- In Vitoria, the University of Melbourne is collaborating with their government agency to develop 3D ePlan for 3D cadastres implementation by 2025 (Rajabifard et al.)

- 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

Field measurement to CAD, then PDF to submit



Eyeball check on the PDF

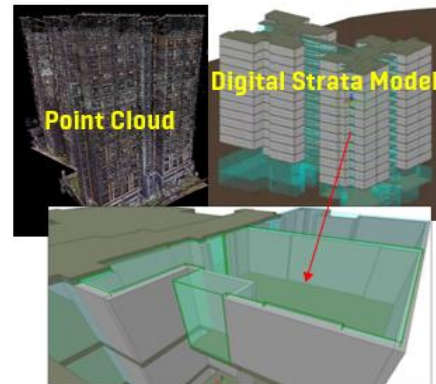


## Moving forward: 3D strata survey submission workflow

Laser Scanning



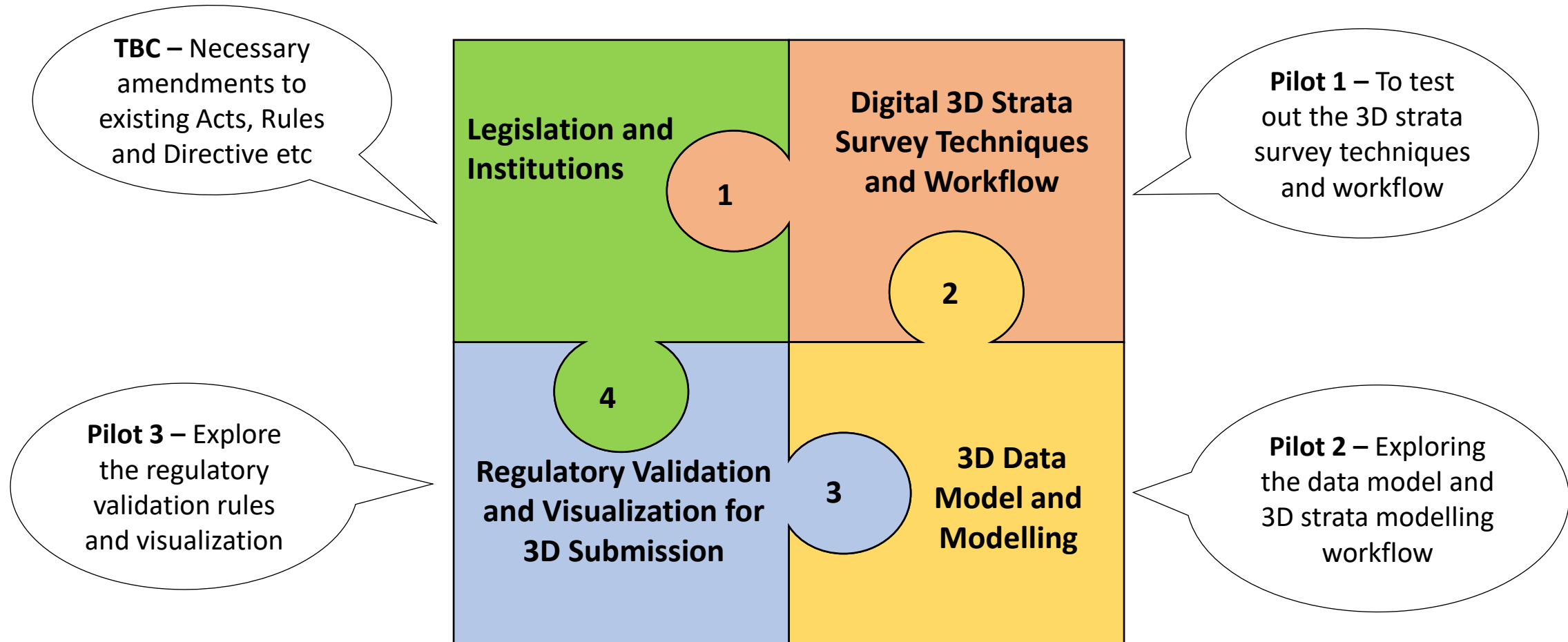
3D Strata Modelling



Auto-check against Regulatory Rules



# Key work areas for 3D strata

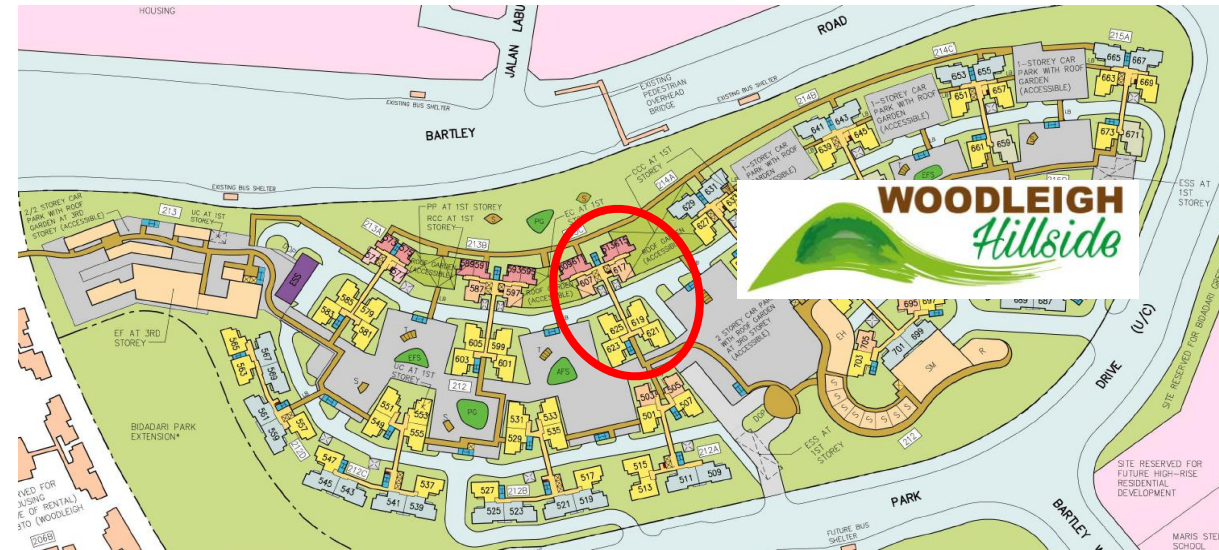


# Pilot 1 – Digital 3D Strata Survey

**1.Objective** - Aims to figure out the workable workflow for as-built 3D digital strata survey using laser scanning and BIM technologies.

**2.Pilot site** – A newly built public housing estate (HDB)

- Block 213C - typical building and ready for strata survey
  - 16 floors
  - 130 housing units
  - lift cores, staircases, long corridors
  - a childcare center at ground level

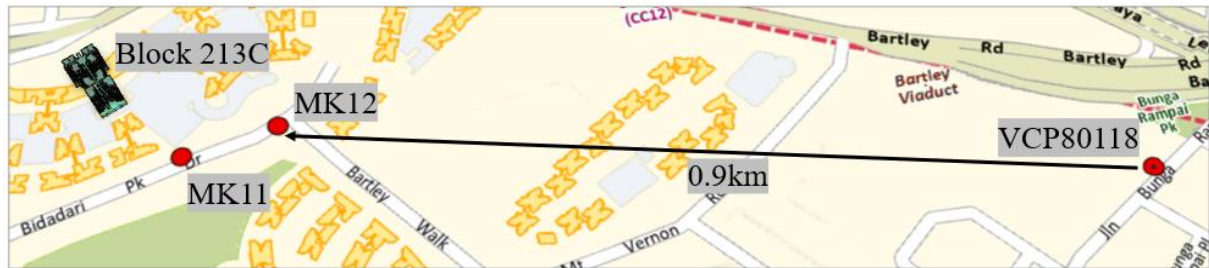




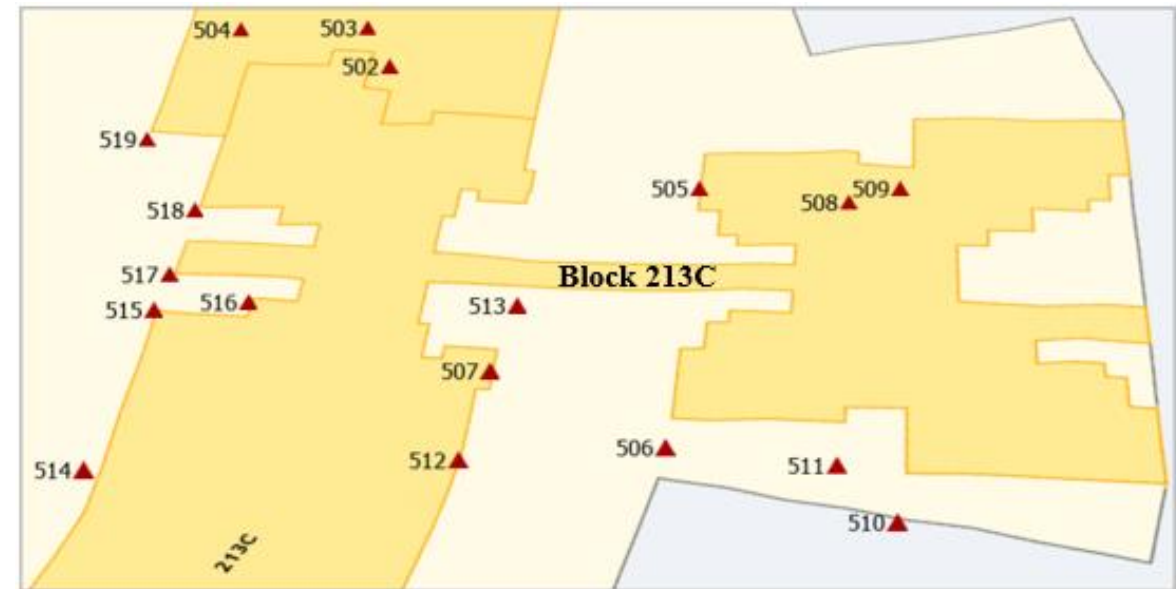
# Pilot 1 – Digital 3D Strata Survey

## 3. Workflow

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



Nearest VCP and new RTK points



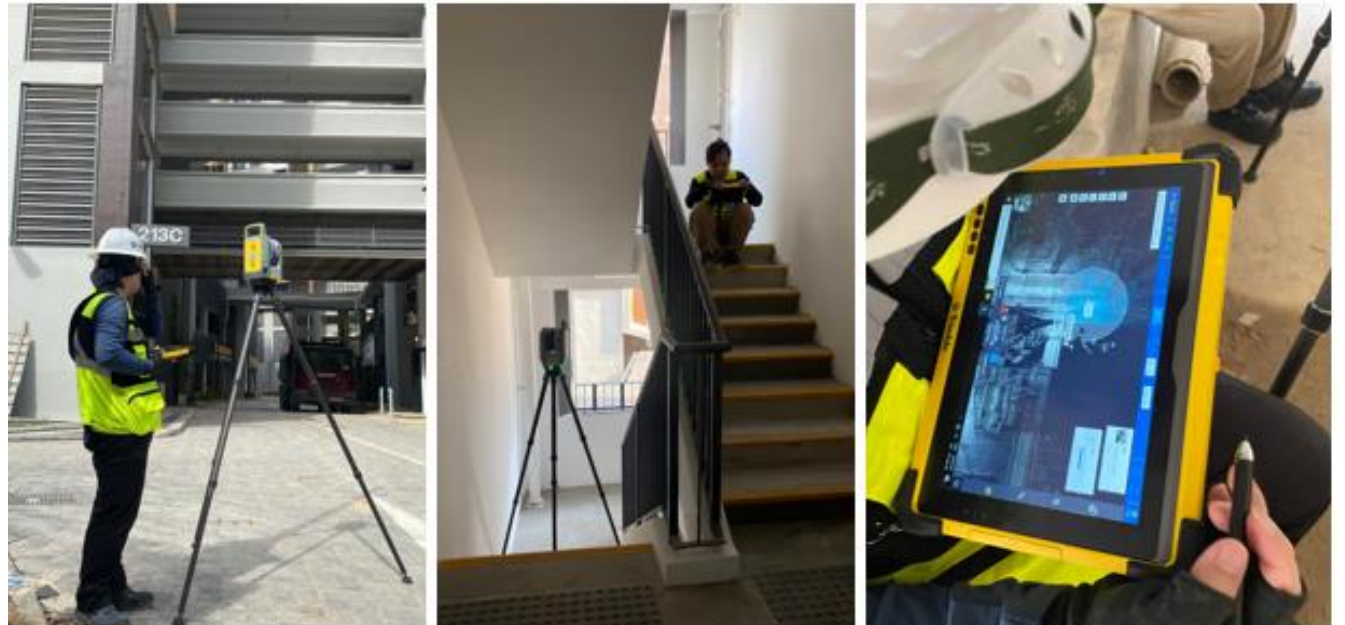
Newly established control points surrounding Block 213C

# Pilot 1 – Digital 3D Strata Survey

## 2) Scanning on site

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

- Features to be scanned
  - exterior for the entire building
  - every individual unit
  - staircases
  - corridors
  - aircon ledge



# Pilot 1 – Digital 3D Strata Survey

## 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
- High-end PC/Laptop is essential for point cloud processing
- The combined point cloud was exported to Autodesk Redcap format for next step

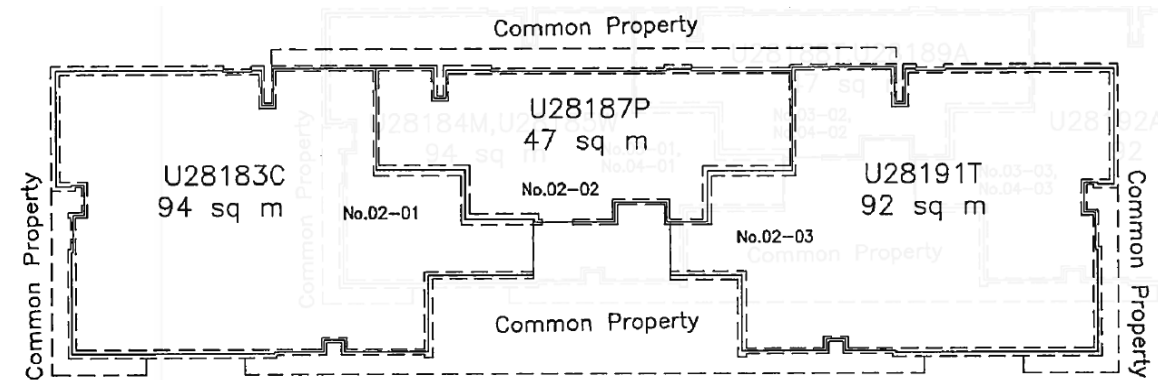


Point cloud of the Block 213C

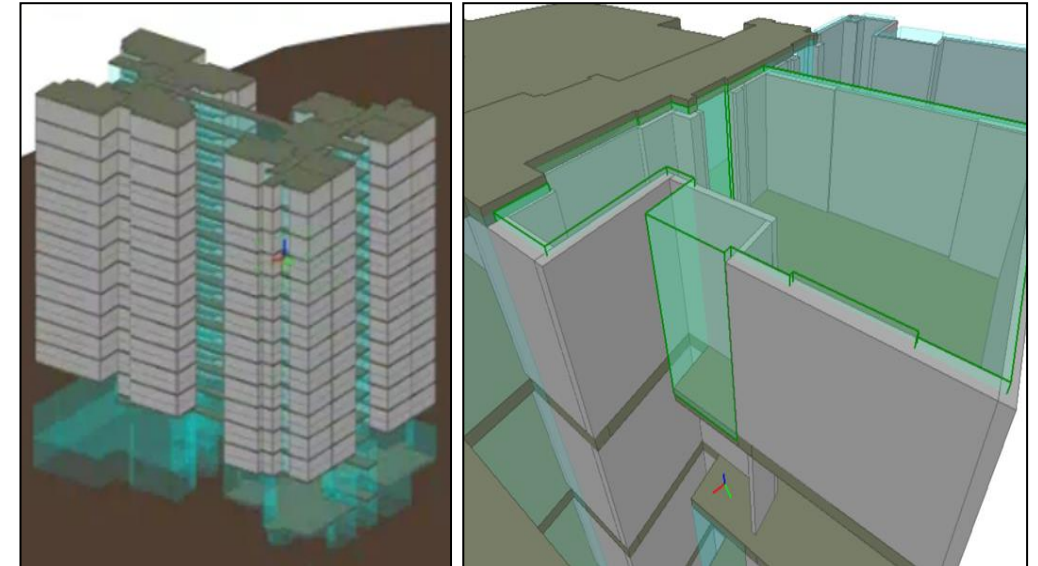
# Pilot 1 – Digital 3D Strata Survey

## 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



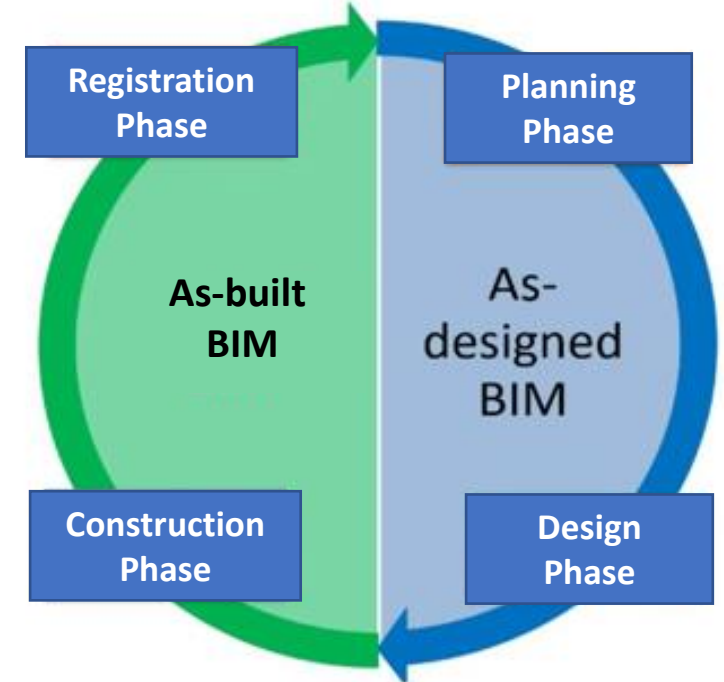
3D Strata Model contains 3D physical structures and 3D legal space

# Pilot 2 – 3D Strata Modelling

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)



# Pilot 2 – 3D Strata Modelling

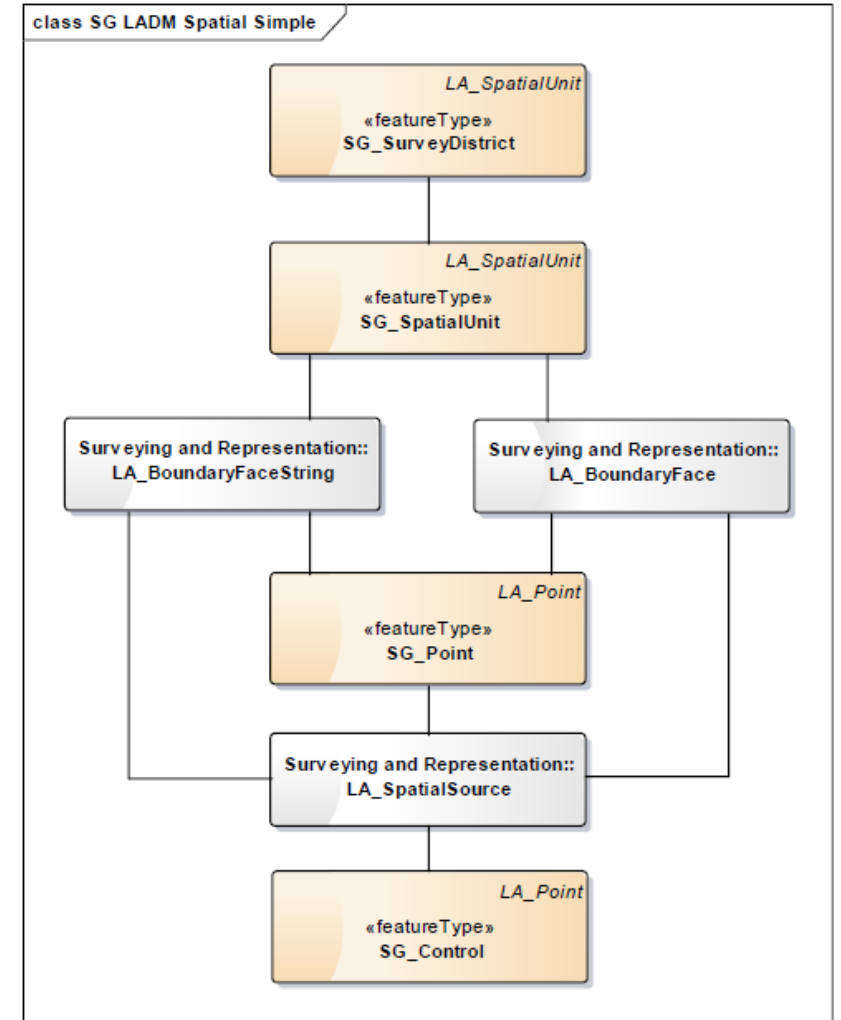
## 3. 3D Data Model and Modelling Methodologies

### 1) Adopt LADM as the foundation 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 requirements



# Pilot 2 – 3D Strata Modelling

## 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)
Strata Lot	ifcSpace	STRATALOT	SGPset_StrataLot
Accessory Lot	ifcSpace	ACCESSORYLOT	SGPset_Accessory Lot
Common Property	ifcSpace	COMMONPROPERTY	SGPset_CommonProperty
Void	ifcSpace	VOID	SGPset_Void

SLA 3D Strata Elements to be mapped to the IFC entities

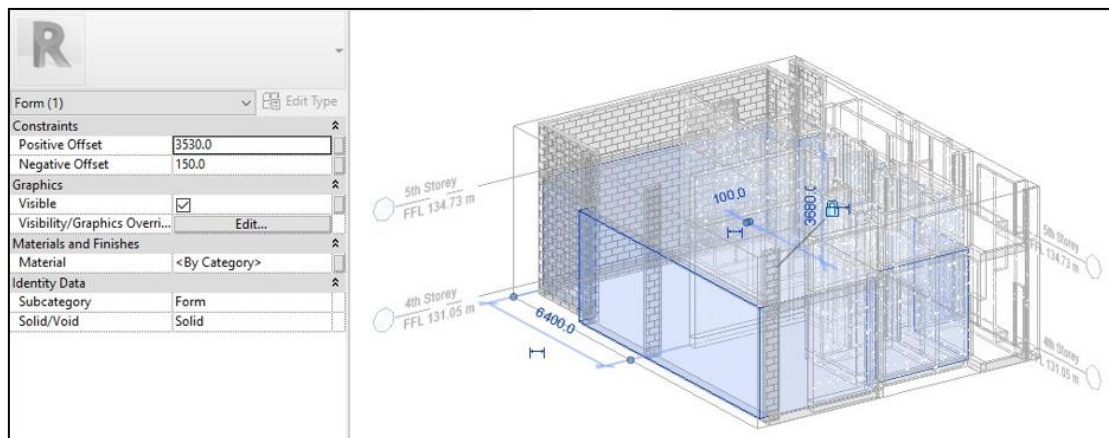
IFC4 (USERDEFINED) IFC-SG_PropertySet	IFC4 (USERDEFINED) IFC-SG_PropertyName	Property Type	Sample Values
SGPset_StrataLot	StrataLotNumber	Label	MK03-U017049L
	StrataLotArea	Area	120
	LotStatus	Label	Live
	ParcelType	Label	Strata
	ResidingOnLandLot	Label	MK03-01847M
	SVYFileNumber	Label	0226-1985
	TypicalFloor	Boolean	TRUE
	UnitNumber	Label	05-02

Mapping strata attributes to IFC-SG PropertySet

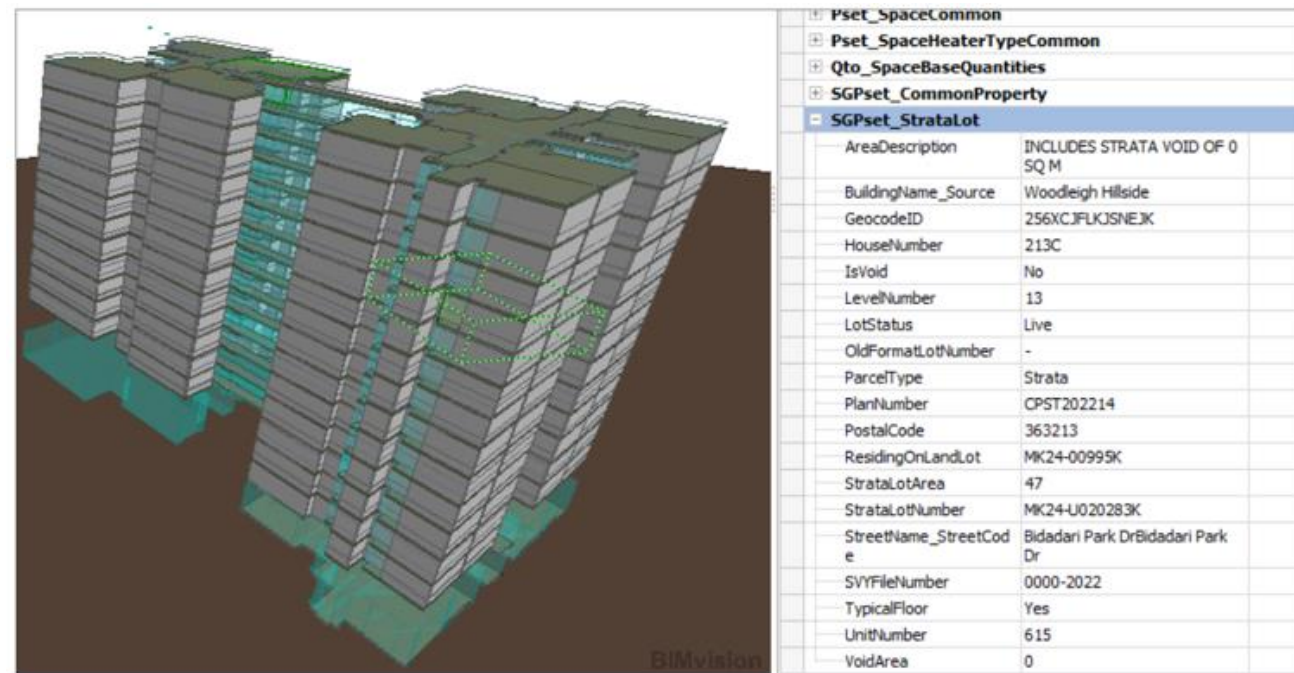
# Pilot 2 – 3D Strata Modelling

## 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



Using Mass family to create 3D strata boundary



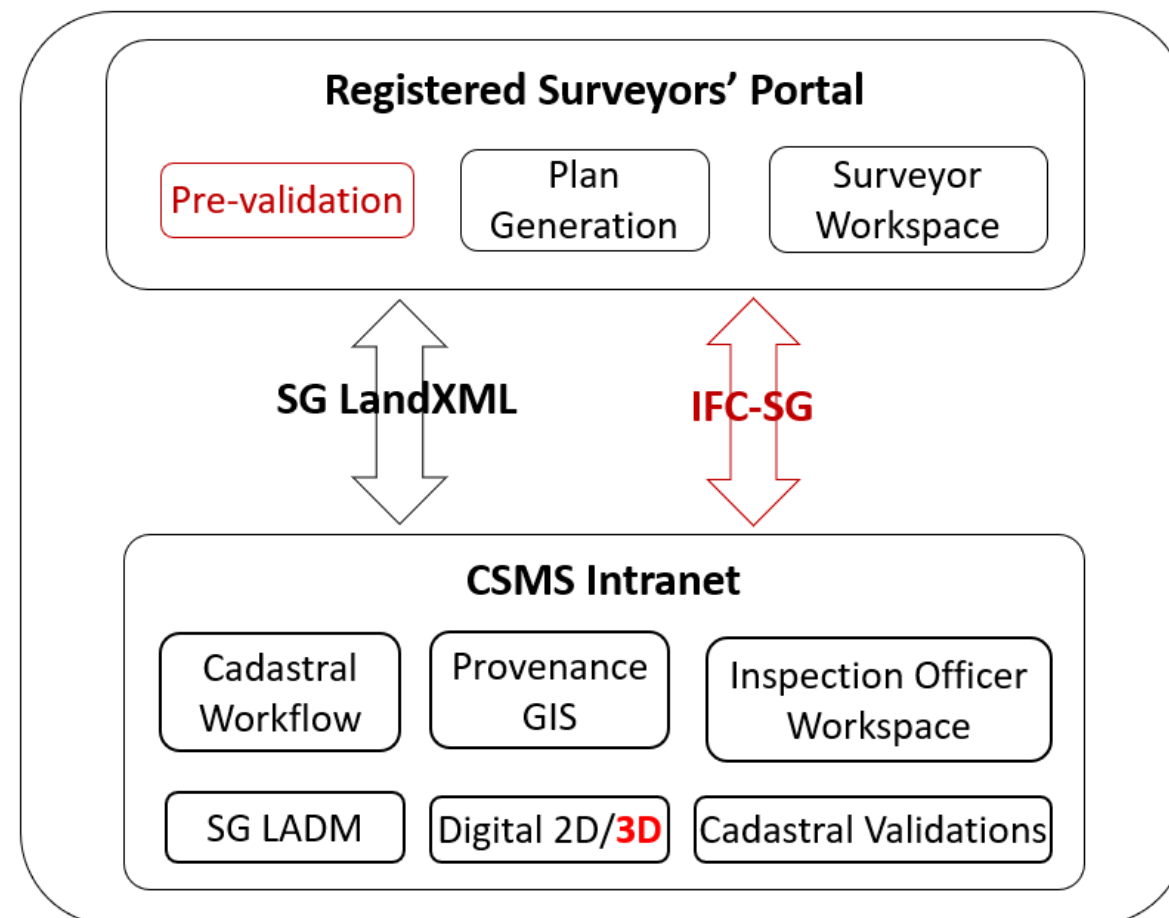
Final As-built 3D strata model of Block 213C



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

**1. Objective** - Aims to develop 3D validation rules and process, and the 3D viewer, to support the 3D strata submission

\* 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 initially;
- 5) develop the intelligent validating process (e.g, automated validation), 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.



## Concluding Remarks



- 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



Email: [wu\\_defu@sla.gov.sg](mailto:wu_defu@sla.gov.sg)