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A New Method for Integrating 3D Spatial Information of Vertically Stratified Ownership Properties into the Property Map Base

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ACKNOWLEDGMENT

3D Property Ownership Map Base Project for Smart Urban Land Administration

Australian Research Council Linkage Project
2017-2019 (LP160100292)



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This project aims to develop solutions for accommodating 3D data derived from regulatory urban subdivision processes into the current 2D property map base.



Environment,
Land, Water
and Planning



Journey - Major Projects

National
Infrastructure for
Land Information
2010-2013



Land and Property
Information in 3D
2012-2016



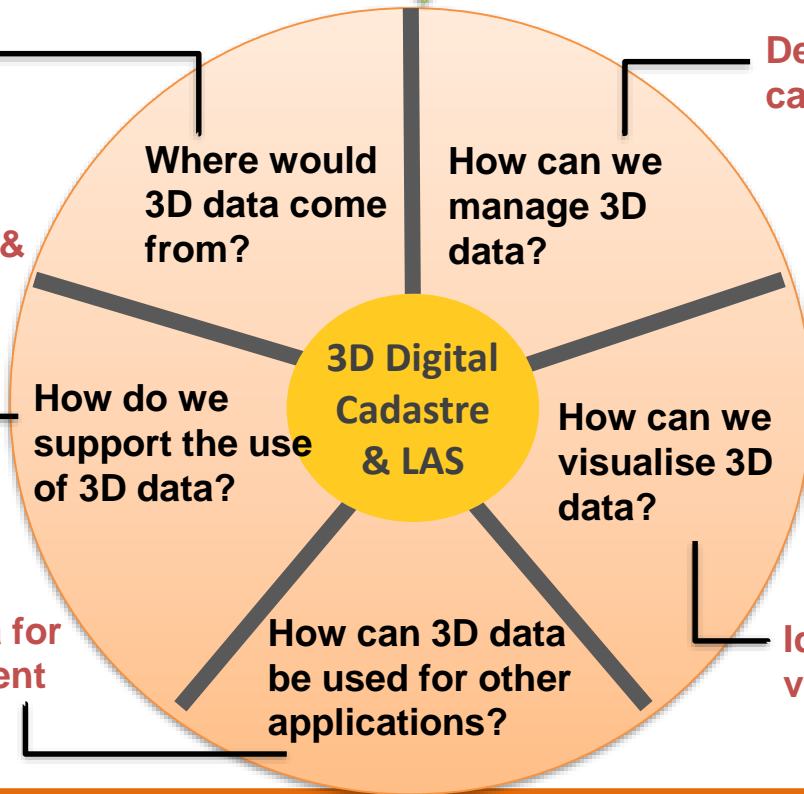
3D Property Map
Base for Smart Urban
Land Administration
2017-2020



Identification of data
sourcing methods

Identification of key
institutional challenges &
proposing a roadmap

Using 3D cadastral data for
flood damage assessment



Development of two 3D
cadastral data models

Identification of more than 60
visualisation requirements



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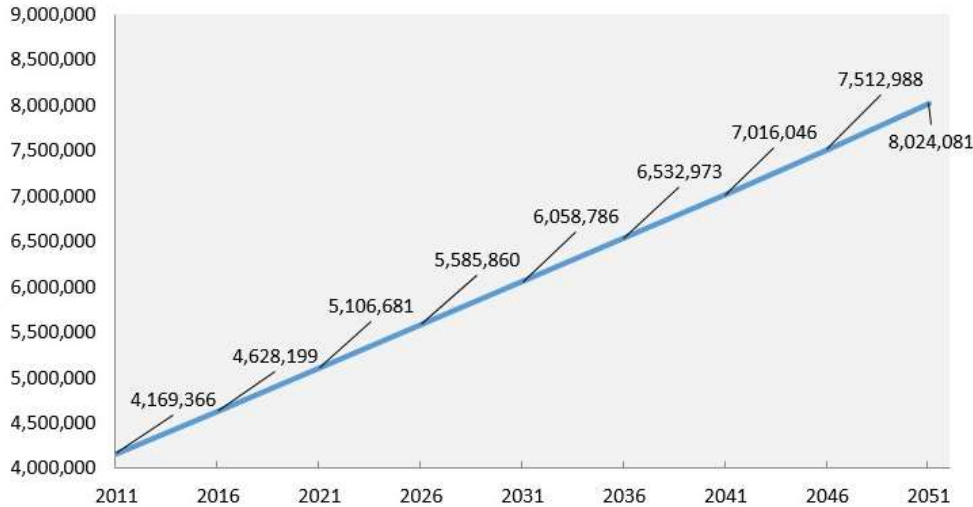


Urbanisation and Complex Developments

Urban environments are growing in the vertical dimension as result of urbanisation

Melbourne Metro Population Projections

Source: Victorian Department of Environment, Land, Water and Planning

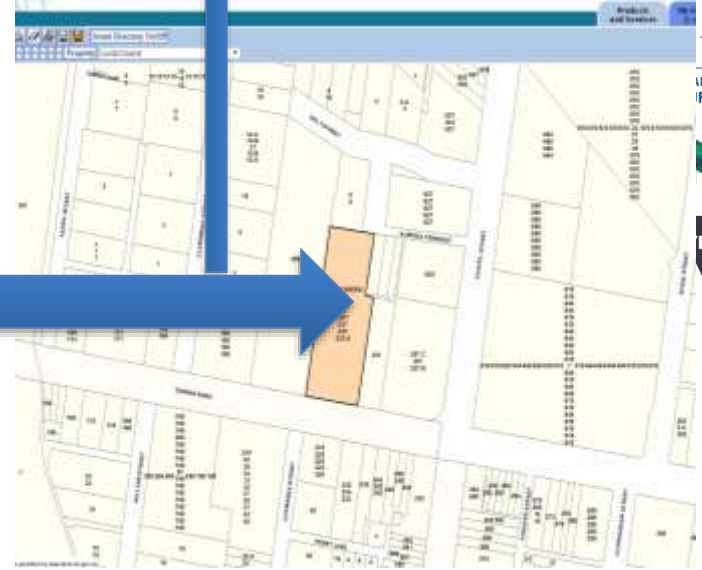
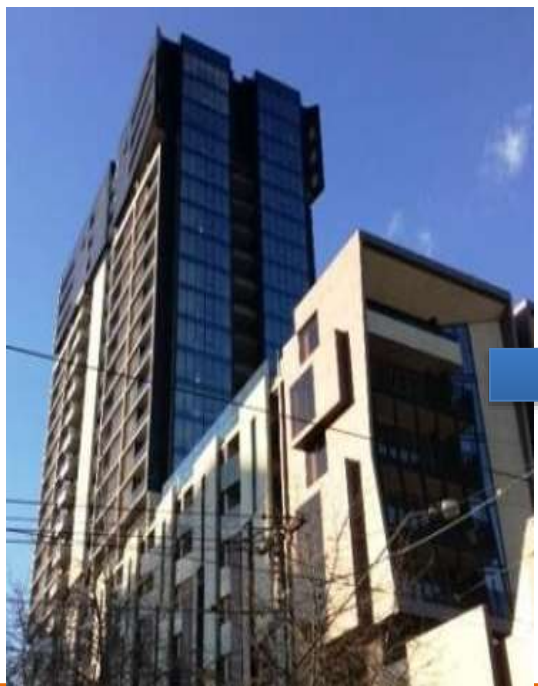


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Current Property Map Base are 2D

- The spatial dimensions of properties located **above and below the ground** are not represented in property map bases of most jurisdictions around the world.
- Current approach relying on **2D subdivision plans** provides a **fragmented representation** of spatial arrangements of vertically located properties.



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Consequences of 2D Approach

- **Extra surveying activities** in complex ownership situations.
- **Costs associated with duplication** of 3D spatial information.
- It **affects the reputation of authorities** responsible for maintaining the property map base and providing critical spatial information services to the community.
- **Unpredictable damages** can be done to other assets, particularly those assets located below the ground.
- **Ineffective support for spatially enable decision making** in managing and planning other aspects of urban settings (e.g. launching National Broadband Network for multi-level developments)



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Property Map Base

- **Property map bases represent the most complete, authoritative graphical representation of land parcel and property boundaries** (cadastral information).
- **Property map bases** are core business for land registries, national mapping agencies and local governments.
- **Property map bases are an enabling infrastructure and a source of intelligence** to support land and property decision-making across government, businesses and communities.



Challenges in Developing a 3D Property Map Base

- **Spatial Integrity Challenges**

- A single 3D property object is defined by a valid volume.
- Spatial validity of legal interests associated with a set of 3D property objects (e.g. Common properties) or the whole 3D property map base.

- **Challenges in 3D Boundary Query and Analysis**

- An appropriate spatial query language to identify the spatial relationships between 3D property boundaries and their corresponding physical elements.



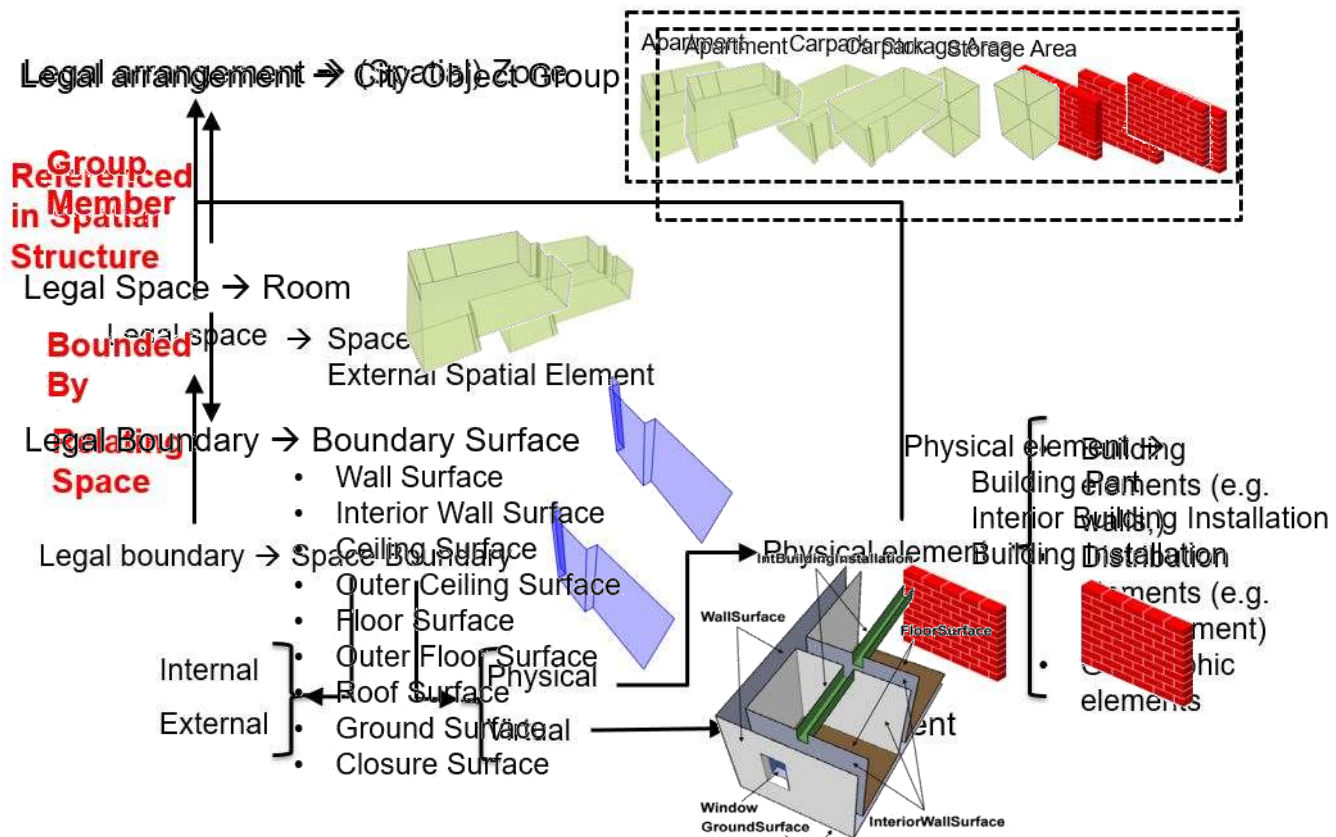
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Spatial Data Models for 3D Property Map Base

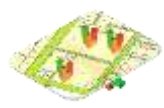
- LADM (Land Administration Domain Model)
- IFC (Building Information Modelling)
- CityGML (3D City Information Models)



(Nagel et al., 2000)



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Potential 3D Platforms

- Spatial Databases (Oracle Spatial, PostGIS)
 - These DBs provide the ability to store and manage 3D spatial data
- 3D City Database:
 - A free geospatial database to managing 3D urban information models
 - Based on the CityGML schema
 - Enables complex analyses in the urban context
- BIMServer
 - An open source server for managing BIM models on the cloud
 - Based on IFC schema
 - Querying and visualising BIM models on the web



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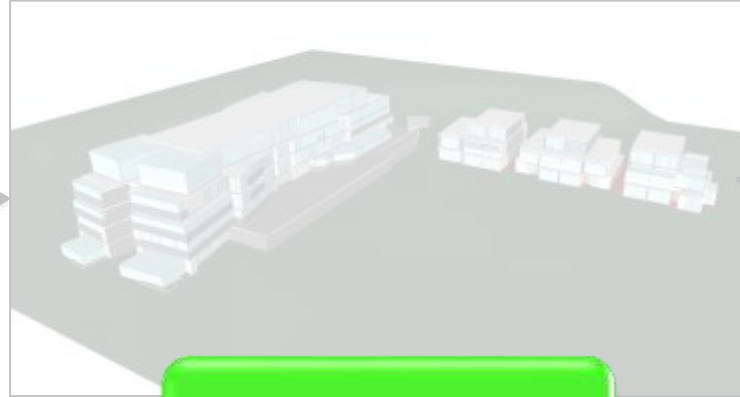
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Pathway Towards 3D Property Map Base

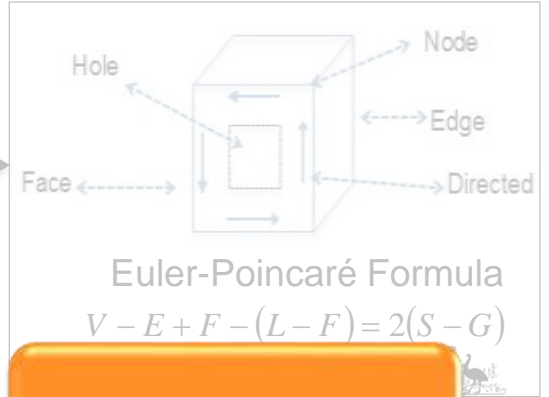
Subdivision Plan



3D Digital Subdivision Model



Validate Model



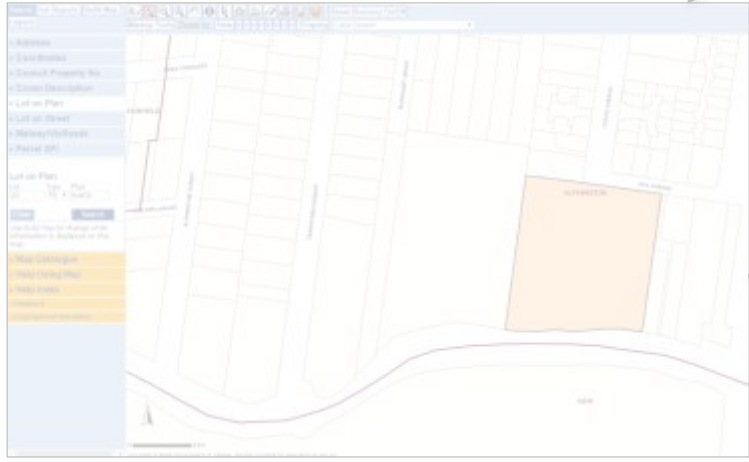
Constructing

Validating

Querying and Analysis

Model into base

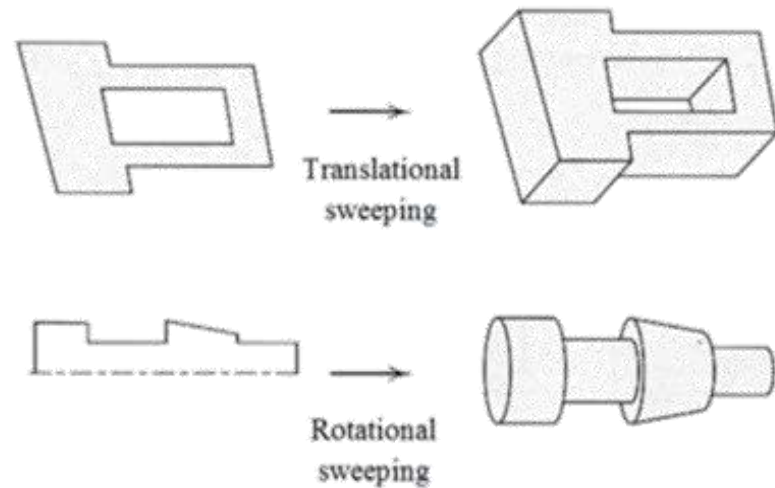
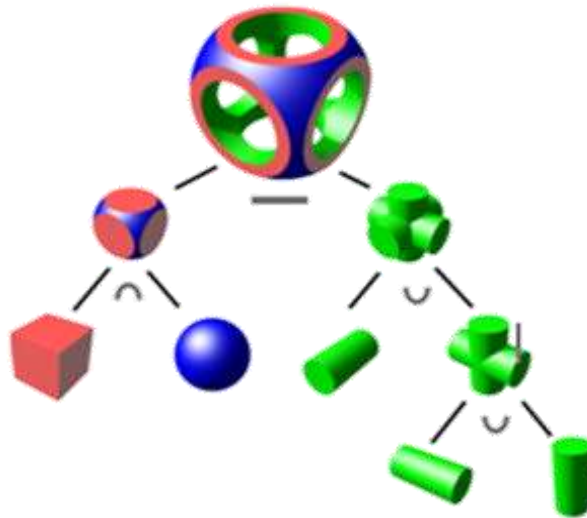
Spatial Property



Constructing 3D Digital Property Models

User Friendly Solid Modelling Approaches in **CAD** and **BIM**

- Constructive Solid Geometry (**CSG**)
- Sweeping



(Wikipedia, 2014), (Anand, 1996)

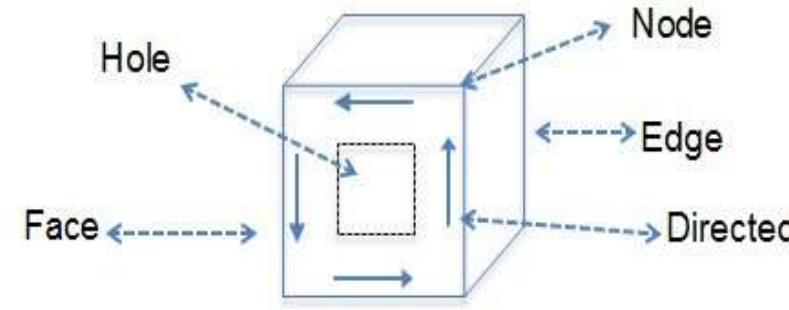


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Validating 3D Digital Property Models

- To adopt the **boundary representation (B-rep)** with **full Topology of 3D property objects** and develop **process** for engineering **validation rules**.
- The geometry of 3D property objects (could be in **Constructive Solid Geometry-CSG** or **sweeping solid**), should be converted into **B-rep-based solid models**.
- Geometrical rules specific to 3D property objects (eg. **no overlaps/no gaps**) must be applied.

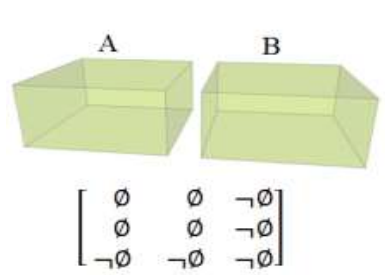


$$F - E + V - L = 2(S - G)$$

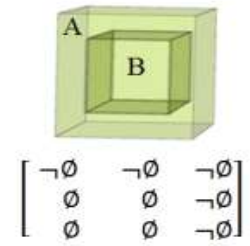
3D Spatial Query and Analysis

Topological Operators – The 9-Intersection Model

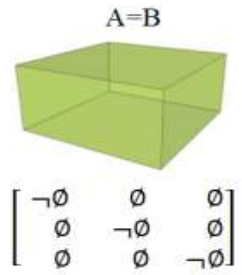
$$I = \begin{bmatrix} A^0 \cap B^0 & A^0 \cap \partial B & A^0 \cap B^e \\ \partial A \cap B^0 & \partial A \cap \partial B & \partial A \cap B^e \\ A^e \cap B^0 & A^e \cap \partial B & A^e \cap B^e \end{bmatrix}$$



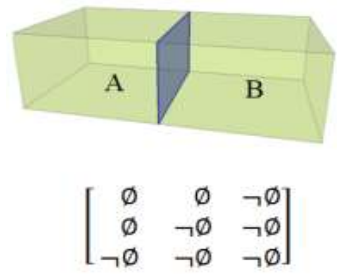
A disjoint B



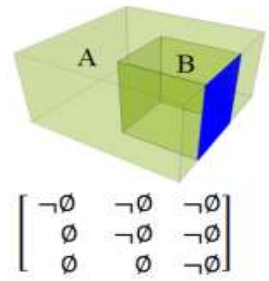
**A contains B
B inside A**



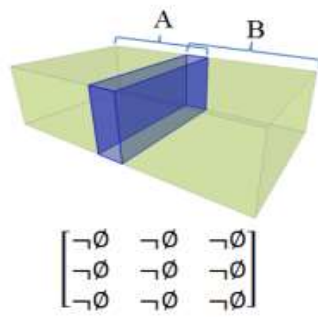
A equals B



A touches B



**A covers B
B covered by A**



A overlaps B



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3D Spatial Query and Analysis

Topological Operators

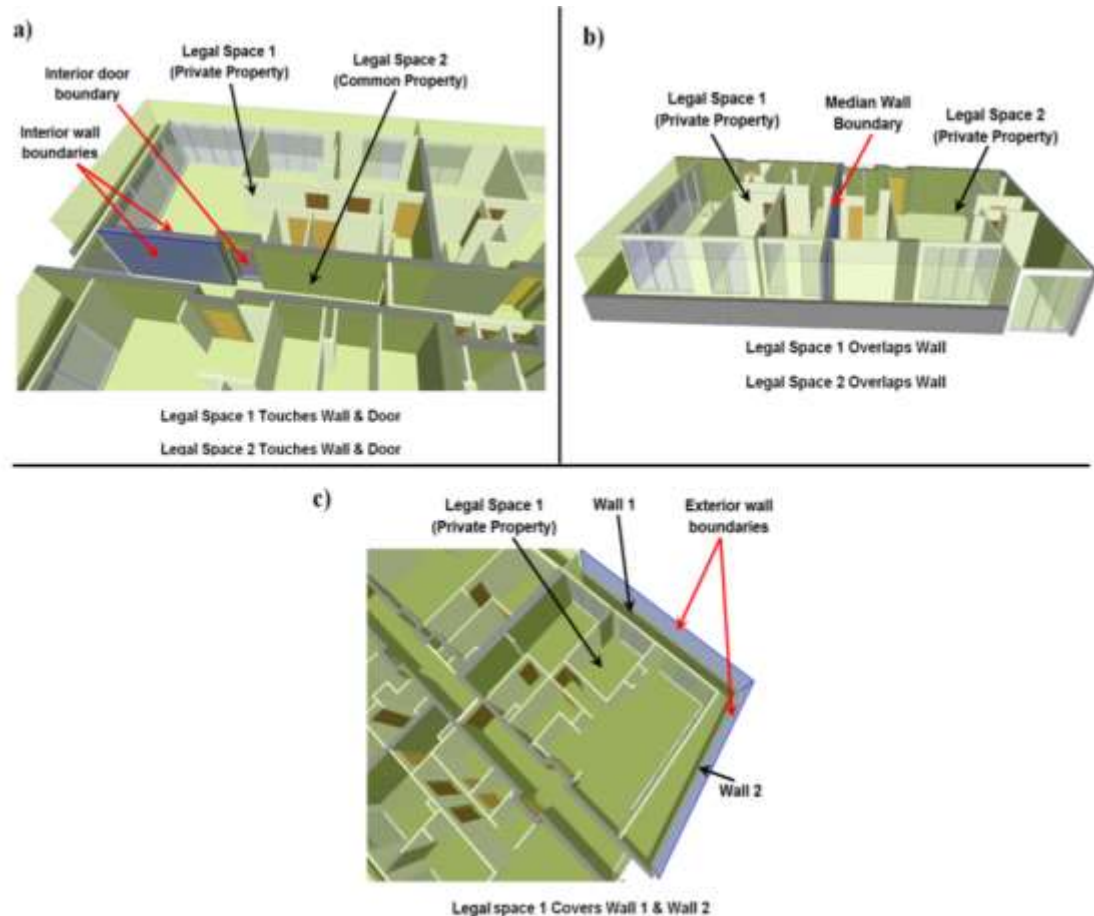
– The 9-Intersection Model

$$I = \begin{bmatrix} A^0 \cap B^0 & A^0 \cap \partial B & A^0 \cap B^e \\ \partial A \cap B^0 & \partial A \cap \partial B & \partial A \cap B^e \\ A^e \cap B^0 & A^e \cap \partial B & A^e \cap B^e \end{bmatrix}$$

A Touches B → Interior Boundary

A Overlaps B → Median Boundary

A Covers B → Exterior Boundary



New Attributes of 3D Property Map Base

- Spatial location of vertically located properties can be clearly determined in 3D property map base.
- **Changes in current practices:** Stakeholders need to interact and communicate in a 3D digital environment.
- The authorities can make better decisions when a new development is constructed, **3D property map base can represent how** this development will affect surrounding properties (underground/aboveground).



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New Attributes of 3D Property Map Base

Emergence of **new use cases** for property map bases:

- **Estimating the density** of occupancy in 3D space.
- **3D analysis** based on population and employment forecasting to enable capacity modelling of existing and proposed services.
- Produce **interactive and narrative products**, which facilitate better community participation in the decision-making process.



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Obstacles to Realise 3D Property Map Base

- **Institutional barriers** - in the current legislative and policy settings, as well as organisational culture of jurisdictions.
- The new **3D digital validation rules** must be **rigorously reviewed and approved** by the authoritative organisations.
- **Lack of required software and hardware across the organisations** for processing and rendering 3D digital data.



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Takeaway Messages



- **3D property map base** could provide **solutions to resolve spatial problems** in communicating and managing vertically stratified properties.
- Development of 3D property map base entails **technical and institutional challenges**.
- A new approach for integrating 3D property information - vertically stratified ownership properties, into the current 2D property map base was proposed.
- The integrated 3D digital representation of the property map base would provide **intelligence in making spatial decisions with legal ownership of underground and above ground properties**.



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Thank You

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