Fit For Purpose 2D Cadastres as the Foundation for 3D Cadastral Modelling and Digital Twins. Comparing Different Solutions from Australia and Indonesia.

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Key words: Fit for Purpose, 3D Cadastral Modelling, Digital Twin

SUMMARY

The transition from 2D cadastral databases to 3D cadastral modelling in most jurisdictions faces a severe lack of the height data required for 3D representation of existing Titles. Many jurisdictions are now creating 3D Cadastral Data Models and are requiring height data relative to a standard datum that can define 3D height extents on new Strata/Stratum/Apartment/Condominium Titles. BIM models will take that to the highest level of detail, but they are not yet widely available.

Existing 3D titles have been created intuitively by defining title extents by existing structures like walls & floors with generic consideration of the associated Rights, Restrictions and Responsibilities (RRRs) like building structural integrity, access, and servicing. This has proven to be an effective method to manage the complexity of 3D Titles for individual buildings but does not provide the geometry for 3D cadastral database modelling.

The first step in progressing towards a useful Digital Twin is to model these historical 3D spaces using a Fit for Purpose (FFP) strategy. No jurisdiction can afford to survey existing 3D Titles so the challenge is to provide a cost-effective solution.

Standard datums and geodetic reference zones are the supporting infrastructure to any strategic modelling of 2D and 3D cadastres. Developed economies are well down this path but developing land systems like parts of Indonesia have progressed this but the extensive data management challenge means that local access to accurate coordinated survey control points with heights is not always available. This requires a pragmatic FFP desktop approach to collecting data to model 3D cadastres from existing plan records with data from any available imagery or other (affordable) technologies (scanning, LIDAR, etc,).

FFP height determinations can be applied by using desktop or other estimates of floor heights to produce 3D models related to standard datums or simply relative to the ground.

The priority is to create a FFP model where all 3D entities are reasonably recognisable by all stakeholders and will identify all those entities for registration in a land administration database for taxation and other needs. This is a representative model, not a boundary definition so spatial integrity is a minor consideration. This type of solution can be achieved now. The presentation will outline practical solutions of different levels of FFP 3D modelling compiled from the Northern Territory in Australia and Indonesia.

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1.0 INTRODUCTION

Digital land administration technologies (Digital Twins, BIM models, etc) have the capacity now to manage and spatially represent 2D & 3D Land Titles across cities and beyond. Modern digital survey data can be automatically ingested into spatial databases, but most jurisdictions face a lack of the smart digital data required for the transition from 2D cadastral databases to 3D cadastral modelling. This is multiplied considerably where there is limited or no existing spatial documentation in 2D or 3D. Fit For Purpose (FFP) enabled considerable efficiencies in creating 2D land administration databases using less rigorous survey methods and spatial tools. FFP is even more relevant to representing 3D property extents.

This paper looks at some examples of FFP technical outcomes and business case options and what governments will need to consider as they move towards modelling 3D cadastre. Those examples come from Australia and Indonesia which could be considered developed countries but due to the population and extents of Indonesia there are many areas that would be relevant to land administration in a jurisdiction considered to have developing economic status.

2.0 THE CAPACITY OF DIGITAL TECHNOLOGY FOR ADMINISTERING AND MODELLING 3D CADASTRE.

Digital Twins & BIMs can be efficient property database solutions that incorporate large data storehouses but require considerable investment in data input and formatting.

The diagrams below outline some outcomes from different jurisdictions in Australia and Indonesia. They highlight technology has the capacity to manage complexity and big data but at what cost and what level of detail is cost effective for government.

Figure 1 below represent outcomes from different jurisdictions. They outline various sources, methods, level of cadastral detail, etc, that include:

- Strata Plans
- Stratum Plans
- Lidar
- BIM
- Field survey

Data sources and methods of some of the diagrams are outlined further in the paper.

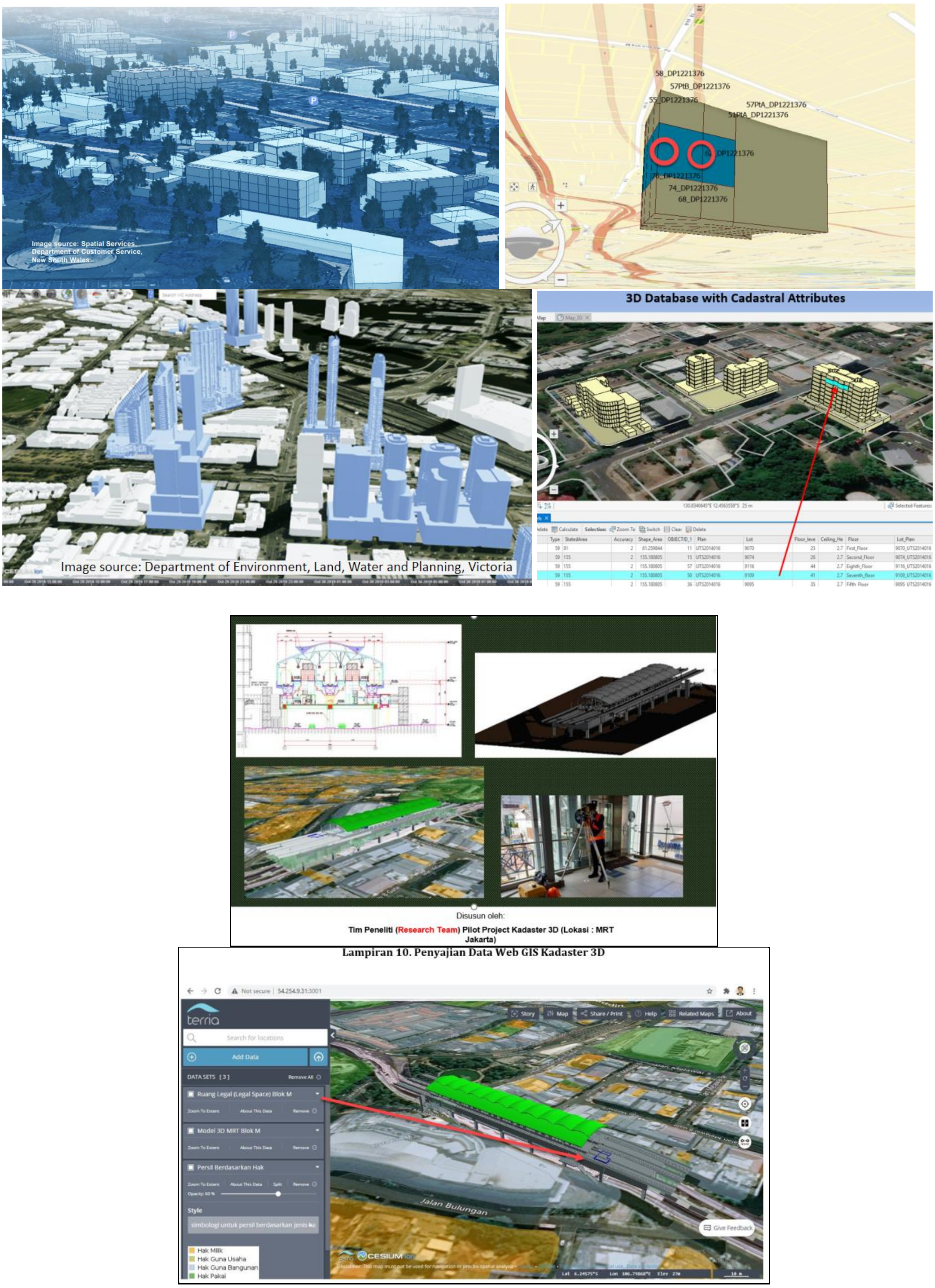
Image source: Spatial Services, Department of Customer Service, New South Wales
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3D Database with Cadastral Attributes
Image source: Department of Environment, Land, Water and Planning, Victoria
Disusun oleh:
Tim Peneliti (Research Team) Pilot Project Kadaster 3D (Lokasi : MRT Jakarta)
Lampiran 10. Penyajian Data Web GIS Kadaster 3D
terria
Add Data
Ruang Legal (Legal Space) Blok M
Model 3D MRT Blok M
Persil Berdasarkan Hak
Style
Hak Milik
Hak Guna Usaha
Hak Guna Bangunan
Hak Pakai
Jalan Bulungan
CESIUM

Figure 1

2.1 Infrastructure for Digital 3D

Standards are vital to our bigger picture 3D future. All Australian States and Territories have developed local standards over the years but are now looking at a national agenda and international standards to apply. Indonesia has also just released a document "Standards and Procedures For 3-Dimensional Models for Apartment Units". Further details are outlined further below.

Standards required:

2.1.1 Data models

- 2D - National and international standard data models have been accessible for many years.
- 3D data models

In Australia there is currently an initiative to develop a 2D & 3D Cadastral Survey Data Model (3D CSDM) standard for Australia and NZ through the Intergovernmental Committee for Survey and Mapping (ICSM). ICSM is made up of seven different States, Territories and NZ that have evolved their current property legal and administration systems completely independently, even though they all were developed on the back of the Torrens Title system.

The first 3D CSDM project (2021-2022) outcome was a conceptual and logical cadastral data model with a **Data Exchange Option Report** recommending the use of JSON as the encoding standard.

Following on from the first project, a second project has been initiated to exercise and test the model and the proposed JSON encoding mechanism. The project will develop a reference implementation to test the mechanism for transferring 2D cadastral survey data. The 3D elements in the model are not being tested in the same way but will be refined as part of this project. (1)

2.1.2 Height datums

The Geoid is the equipotential world reference surface for GNSS geodetic datums based on Mean Sea Level and serves as an accessible height datum.

Local datums based on survey measurement provide a higher level of height precision. In Australia, AHD (Australian Height Datum) is the national datum based on tide gauge data and expanded across Australia by precise levelling.

2.1.3 Location

WGS84 is the geographic coordinate system representing the spheroid defining the globe. National local coordinate zones then provide mathematical models to minimise distortion due to curvature.

Figure 2 below shows how Australia is divided into zones 6 degrees wide so any 2D and 3D modelling is based on these zones.

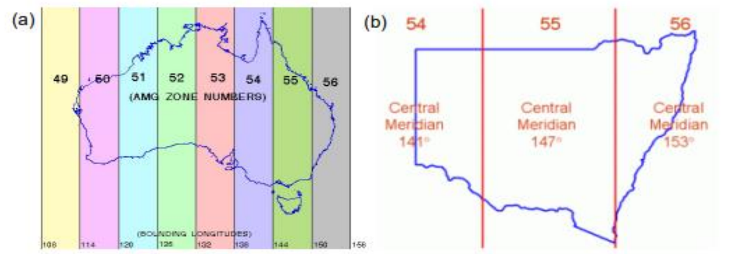


Figure 3: Map Grid of Australia (MGA) zones across (a) Australia and (b) NSW.

Figure 2

2.1.4 3D Database and Modelling Applications

There are various levels GIS applications to be considered, e.g. ESRI, Bentley, QGIS, etc. To generate FFP 3D cadastral models, applications can utilise different data and methods:
- Extrusion of the floor level height of 2D unit parcel plans to a ceiling height
- Creating basic Triangular Irregular Networks (TIN) from points with x,y,z coordinates to represent all features (faces, etc) of a 3D unit.

Choosing which application meets their technical and commercial needs is a major consideration of any jurisdiction.

2.1.5 Governance - Existing Title Legislation/Regulations For 3D Cadastre

In most jurisdictions, 3D titles have been defined as a subdivision of a current land parcel by a unique title identifier referencing a survey/map in a registry or address of individual 3D titles. Different levels of identification and spatial representation could include:
- The address of a flat/apartment/condominium
- A plan/diagram of title extents by referencing existing structures like walls & floors with generic consideration of the associated Rights, Restrictions and Responsibilities (RRRs) like building structural integrity, access, and servicing.

3.0 THE CHALLENGE - TRANSITIONING EXISTING 3D PROPERTY INFORMATION TO POPULATE DIGITAL MODELS – WHAT DATA IS AVAILABLE AND HOW FAR DO YOU GO?

While jurisdictions differ, the documentation representing most 3D titles rarely includes references to the standards referenced above. Trying to mathematically define title extents of existing structures like surfaces and centres walls & floors and the associated RRRs is not a simple exercise. The intuitive nature of referencing the 3D title extents has proven to be an effective method to manage the complexity of 3D Titles for individual buildings but does not provide the geometry for 3D cadastral database modelling.

Whilst we recognise technology has capacity, the simpler the processes that are adopted the greater the outcomes will be. Some examples are outlined below.

3.1 Examples

NEW SOUTH WALES - Figure 3 - Digital Twin showing internal building subdivisions – generated from various data sources: Strata plans, lidar etc.

Figure 3

Figure 4 below shows a model generated from a Stratum Title plan of titles defining 3D spaces around road tunnels under existing titles. The subterranean title boundaries are defined by the existing surface cadastre but are limited in height based on standard datum. **Figure 5** title plan shows an elevation and **Figures 6 & 7** identify different ownership at different levels. This basic representation allows separate ownership of the underground tunnel without affecting surface ownership.

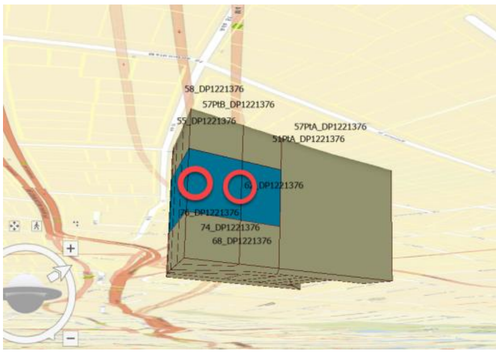


Figure 4

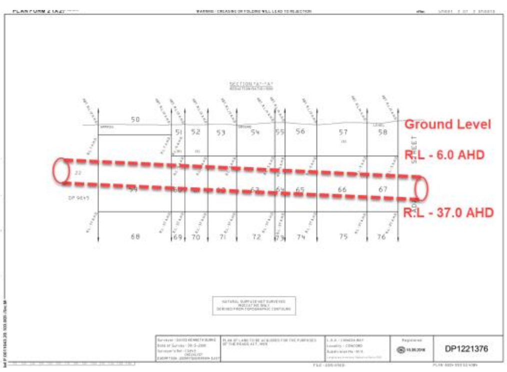


Figure 5

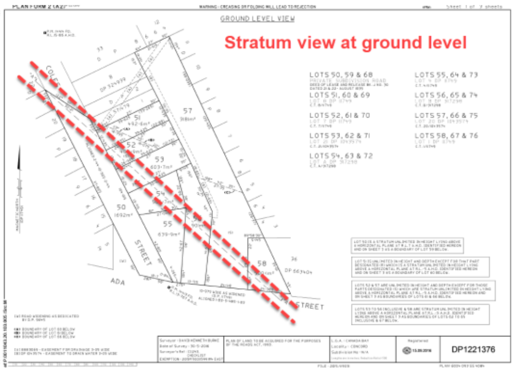


Figure 6

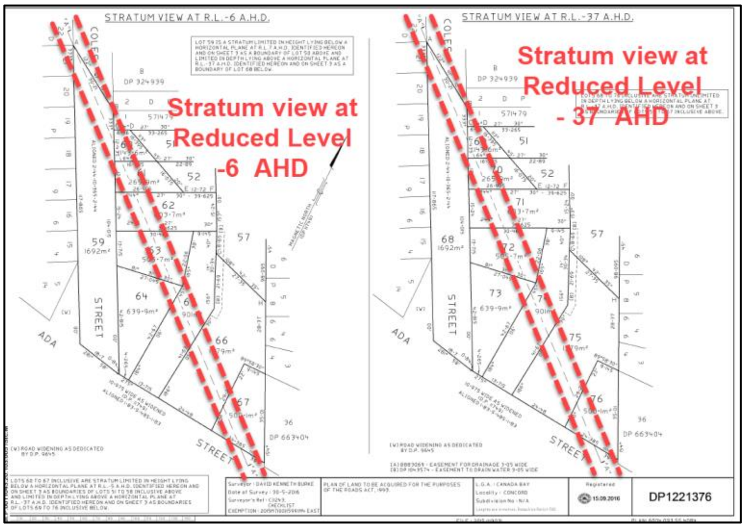


Figure 7

Victoria – Digital Twin from Lidar (Figure 8)

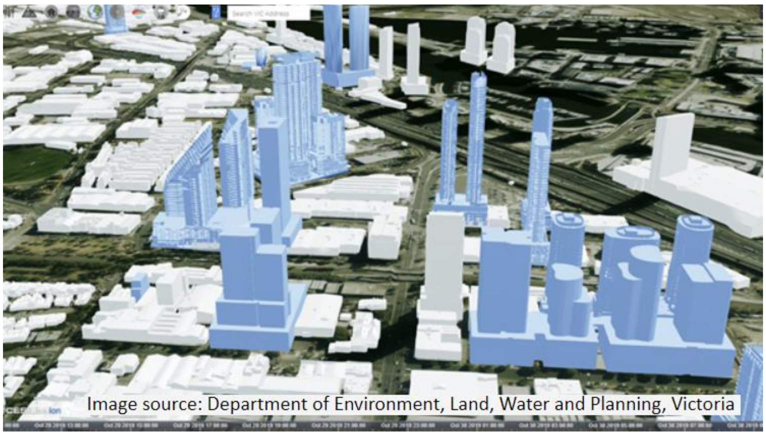


Figure 8

Northern Territory – Figure 9-3D Model generated from Strata Plan shown in Figures 10-11

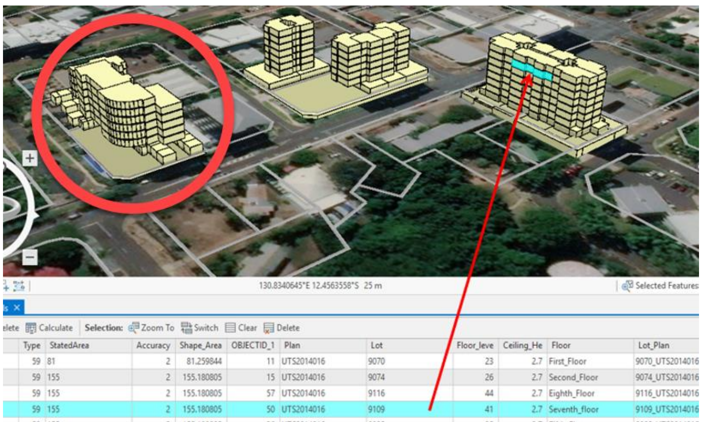
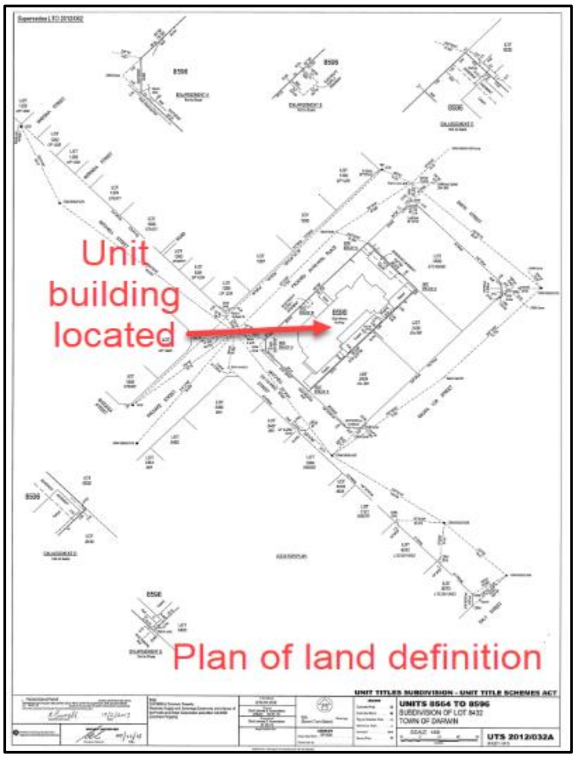


Figure 9



Note:

- No dimensions on provided on a Strata Plan so 2D Unit parcel extents are digitised from Unit diagrams.
- No levels are recorded on Strata Plans so floor and ceiling AHD levels are based on estimates from natural surface and indicative construction dimensions.
- Height gap (300mm) between the ceiling of lower unit and floor level of upper unit represents the structural concrete slab that is deemed Common Property.
- Survey connections from land parcel boundaries to unit plan layout (**See Figure 11)** allows Unit parcels to also be adjusted when spatial upgrading of cadastral database by Least Squares or other measurement based adjustments.

Figure 10

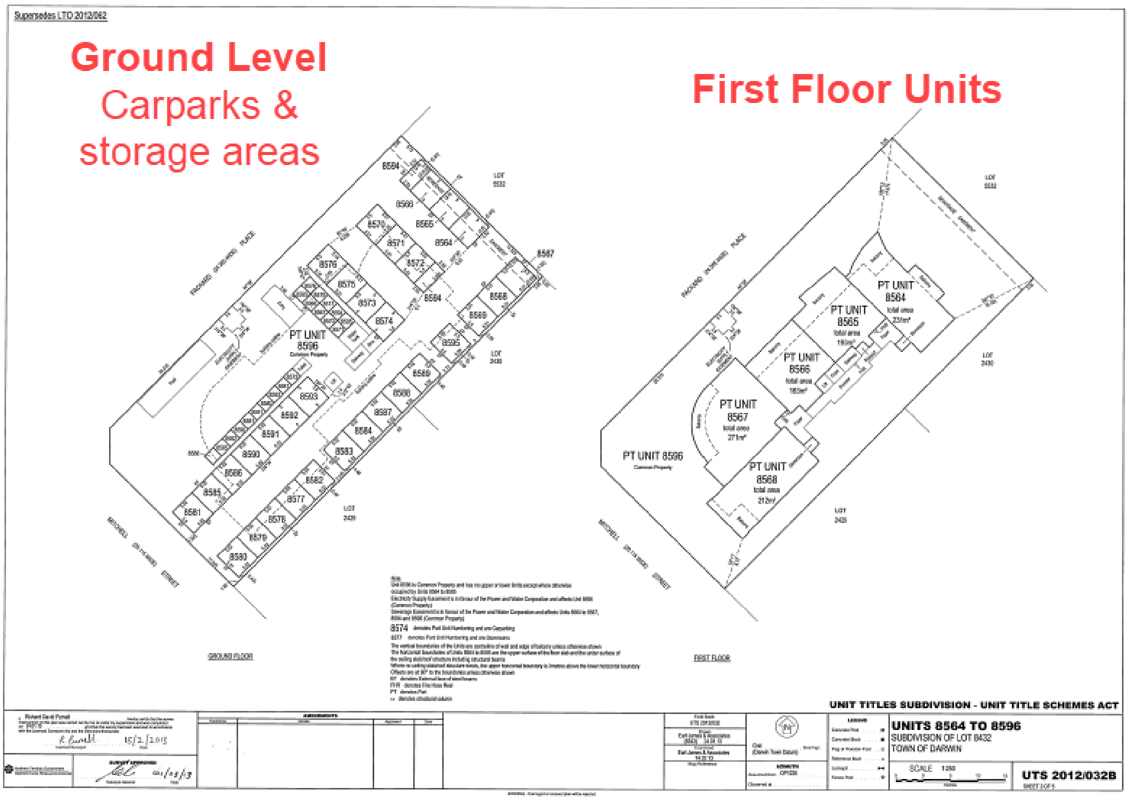


Figure 11

INDONESIA - In December 2023 the Indonesian National Land Agency of the Ministry of Agrarian Affairs and Spatial Planning introduced the ***TECHNICAL INSTRUCTION - STANDARDS AND PROCEDURES FOR 3-DIMENSIONAL MODELS FOR APARTMENT UNITS***

The aim of these regulations are to standardise digital 3D models for new Apartment Units based on survey data defining the completed units. There are 2 Levels of Detail (LOD) that can be presented. The simplest is LOD 1 consists of a block model where a floor plan is extruded to the height of the ceiling. LOD 2 is a 3D model which provides greater detail like roof shape, walls, common areas etc.

2D View	3D View
	

Figure 12

The models are required to use a 3D cartesian coordinate system with the 1984 WGS ellipsoid and UTM projection and data format is based on the OGC 3D data standard.

3D data standards for apartments unit will be gradually adopted in Jakarta over the course of 2024, with full implementation and potential expansion to other regions planned for 2025.

The issue of populating Digital Twins of existing Units is under consideration. Several possible FFP solutions are outlined below where different levels of resources and methods are used.

Figures 13-14 show an example where minimal survey data from total station and UAV provide a skeleton for accurate location and heights. Remining features can be applied at a desktop level to generate a FFP Digital Twin as shown in **Figure 15**.

Figure 13

(a) (b) (c)

Field Work Image : (a) GNSS CORS, (b) Total Station Reflectorless, (c) UAV Lidar

Figure 14

Figure 15

Figure 17 below shows a dwelling with no records. The building also overhangs a public thoroughfare – options to generate a 3D model include:

- Desktop estimate of building dimensions from terrestrial photography and location from imagery
- Site visit could utilise a tape to identify dimensions and then use imagery for location.
- Site visit with total station and/or GNSS

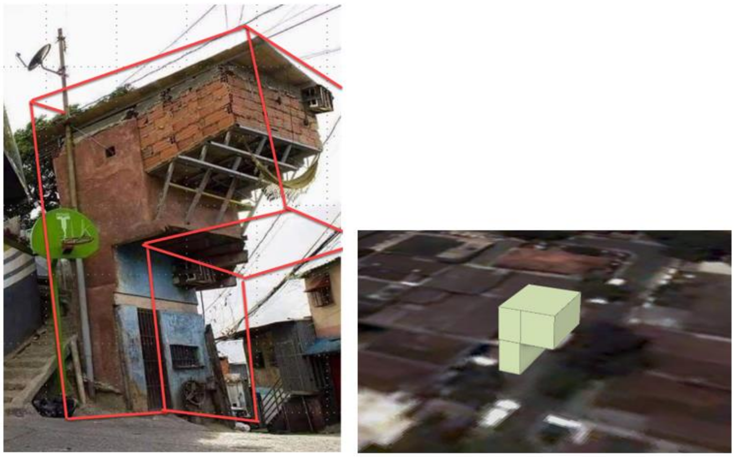


Figure 16

Figure 18 below is a desktop 3D model showing a 3-storey apartment building generated from imagery and estimates of apartment extents to provide a basic model of the building. Floor heights are relative to an assumed ground level of 0.0m. This is based on not having any height data so imagery is on a horizontal plane at 0.0. This minimalist method would facilitate many individual buildings to be simply incorporated into a wider Digital Twin across an urban area to visually identify individual 3D properties relative to each other with any attribution required for land administration. (see also Figure 16)

Whilst minimalist, the height attributes must be dynamic to integrate standard datums as they become available.

Figure 17

4.0 A FIT FOR PURPOSE 3D CADASTRE – THE BUSINESS CASE FOR A (NON-IDENTICAL) DIGITAL TWIN

The previous examples of 3D cadastral modelling identify many and varied issues and outcomes, so the business case is obscure. When trying to populate a Digital Twin with the extents of existing 3D property Titles, applying the normal cost/benefit equation is not possible as there is limited survey data or none. Digital Twins provide many benefits but are difficult to quantify and the costs to include cadastral content are even more difficult to quantify.

The greatest benefits that a FFP Digital Twin would provide to major stakeholders (being government and owners) is 3D dynamic visualisation of approximate property extents and a relationship to adjoining and nearby properties. This then links to unique identification and attribution of properties for land administration purposes.

By taking a FFP approach of not relying on rigorous survey methods, these benefits are achievable in a cost-effective way. The outcome referenced in **Figure 17** above would be cost effective and would reflect a "flat earth" but would still provide the benefits outlined above. To enhance this scenario, LIDAR would provide great value and a more representative 3D outcome. The representative shapes of the buildings would provide some integrity to the location and individual building levels could then be adjusted to a more universal height datum, even if floor levels are still relative to an estimate of the DTM ground level.

A key to a FFP strategy is to represent the most basic of shapes in 3D, being a 2D floorplan with a floor (lower) level and a vertical distance extruded to define the upper surface (also known as 2½D). This simplifies the data required and level of complexity required in the available 3D modelling applications.

Curved, sloping and other surfaces may physically define the extents of a 3D property but will introduce a considerable level of complexity to represent in a machine-readable format. There is also the added complication of needing extensive data models as well as complex applications to read and model those shapes. These types of shapes would only represent a minor percentage of existing 3D Titles, however, they could still be represented in the 3D model in a similar way to **Figure 16** above. This meets the needs of positioning and representing that title in the 3D model & land administration database.

The value proposition is what level of detail meets the needs of stakeholders beyond the FFP outcomes. The outcomes include but are not limited to:

- Property location (2D & 3D) metrics (coordinates & height)
- Property boundary definition relating to the face of internal surfaces (walls, floors, ceilings, etc,)
- Representation of RRRs.
- Digitally representing curved and complex shapes

The value of the spatial database is in the detail that it provides and the level of spatial integrity. The more detail it holds, the more valuable it becomes, but at what cost?

5.0 UTILISING EXISTING SURVEY RECORDS AND OTHER SPATIAL DATA TO FACILITATE FUTURE DIGITAL TWINS

Many jurisdictions like Indonesia are implementing regulations as part of the approval process to generate smarter digital 3D cadastral data. This smart data is more easily incorporated into Digital Twins or even automated. There are also many others that are considering similar strategies, but determining levels of complexity is challenging.

Whilst these strategies are being considered, one simple aspect of an approval could be to require surveyors to record floor levels based on a standard datum on any new development. Providing such level data would be invaluable in the future and implementation could begin immediately.

In NSW there are over 950,000 existing strata titles, so the records of survey plans of unit / apartment titles held by a state or national registry are an obvious FFP data resource. Other levels of government could also hold valuable data collected for building approvals and construction. Documents that could have been held for many years can be scanned. This would provide some detail but often require further scale and location computations/attribution to extract the most value.

Similarly, more recent digital data may be smarter but suffer the same shortcomings of scale and location. Smart geometry can be extracted from CAD drawings or scanned. Automated extraction may provide a smart solution but differences in data format and content may place hurdles in perceived efficiencies, The FFP solution does have limitations with location integrity but the challenge of retrospectively fitting survey/spatial data with standard height datum is significant. This is not an issue when digitally representing individual unit/apartment/condominium developments but collectively a Digital Twin across a wider urban area would need all heights to be on a standard Geoid or local height datum.

No jurisdiction can afford to survey millions of existing 3D Titles so the challenge is to provide a cost-effective solution that:

- is scalable as better data becoming available.
- is mindful of how cadastral databases are to be spatially upgraded. This initially applies to parcel boundaries, but as we progress to 3D titles the same need exists for building extents to be spatially upgraded in 2D.
- integrates with various 3D modelling applications.

Developing the cadastral content of a Digital Twin requires a knowledge of local legislation and regulations and what is going to be represented in the Digital Twin. As outlined above it is not economically sustainable to digitally represent the true legal extents of 3D property when those legal extents are not recorded or are intuitive so a FFP solution is one that would be relevant to Developed and Developing countries.

REFERENCES

(1) **Intergovernmental Committee on Survey and Mapping (ICSM) – 3D Cadastral Survey Data Model (3DCSDM)** Project. ICSM is a Standing Committee of **ANZLIC – the Australian and New Zealand Spatial Information Council.**

(2) **Indonesian National Land Agency of the Ministry of Agrarian Affairs and Spatial Planning**
PETUNJUK TEKNIS NOMOR 12/Juknis UK.04.01/XII/2023 TENTANG STANDAR DAN PROSEDUR MODEL 3-DIMENSIU NTUK SATUAN RUMAH SUSUN
(TECHNICAL INSTRUCTION NUMBER 12/Juknis UK.04.01/XII/2023 ABOUT 3-DIMENSIONAL MODEL STANDARDS AND PROCEDURES FOR APARTMENT UNITS)
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Northern Territory
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