Aspects of 3D Cadastre- A Case Study in Victoria

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Key words: Land administration system, 2D cadastre, 3D cadastre, 3D RRRs

SUMMARY

Three dimensional (3D) developments of land are common and affect land interests in urban populated areas. Management of 3D land rights, restrictions and responsibilities (3D RRRs) is one of the most important challenges in the current land administration systems which are equipped with cadastres that are only able to maintain 2D spatial information.

3D cadastres would assist management of 3D RRRs. A 3D cadastre should be capable of storing, manipulating, querying, analysis, updating, and visualising 3D land rights, restrictions and responsibilities. 3D cadastral aspects should be considered in any modern system. The legal, institutional and technical aspects of a 3D cadastre provide the framework for its successful development and implementation.

Legal systems would support registration and representation of 3D properties to meet the demands for multiple ownership of land and buildings. Institutional aspects would provide regulations for defining 3D property rights, mechanisms for acquisition 3D data, and the tasks and responsibilities of the public and private sectors. Technical aspects such as 3D data capture, representation, updating and modelling would facilitate the development and implement of 3D cadastre.

This paper presents a case study approach to analyse the technical deficits of current practice of 3D registration in Victoria, Australia. Property legislation has been studied from the first steps of 3D registration until the current amendments. Institutional aspects and concepts are discussed. For technical aspects, the case study uses subdivision plans related to a simple, single-use facility of an underground car park to highlight the technical deficits and opportunities available from a 3D cadastre.

This study shows that Victoria has the potential to accommodate a 3D cadastre. Victoria's property legislation allows registering of 3D properties. There is a unanimous opinion and movement toward the development of the 3D cadastre. However, there remain some obstacles to developing and implementing the 3D cadastre from the technical point of view.

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1. INTRODUCTION

Land is under pressure from human activities in populated areas. Population growth, urbanization and industrialization place more pressure on land use with the need for increased space. Utilisation of the spaces above and below ground level, underground developments, infrastructure facilities, high-rise buildings, and apartments are the results. Developers are forced to construct different types of complex buildings and infrastructures vertically and horizontally above or under each other to make greater use of land and extend the use of land. This three-dimensional (3D) development will affect the interests attached to those land parcels to which these constructions and facilities have been constructed.

Current land administration systems are mainly land parcel based. They cannot effectively represent the complexities of reality. The 2D cadastral systems are not able to manage and represent land ownership rights, restrictions and responsibilities in a 3D context. Current registration of 3D developments in most jurisdictions is based on 2D paper diagrams or drawings as a footprint on deed/title plans or subdivision plans.

On a 2D map, it is difficult to measure the length, area, and volume of a 3D property in the system. Query and spatial analysis cannot be executed, because the digital cadastral database (DCDB) cannot support all 3D data. 3D visualisation is not possible in most jurisdictions, and the public cannot explore the 3D developments as they cannot interact with the 2D plans.

A 3D regime should be considered in three main aspects (Figure 1): legal (which supports the register of 3D properties), institutional (which established relationships between involved parties), and technical (which provides platforms to realise the 3D cadastre). These should be considered in 3D cadastre developments for each jurisdiction.

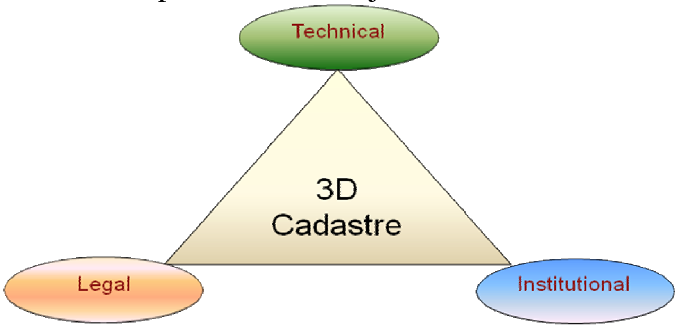

Figure 1. Relationship between different aspects of 3D cadastre

Development of 3D property legislation has been studied from the first steps of 3D registration until the current amendments to meet the demands for multiple ownership of land

and buildings. Institutional aspects and concepts have been reflected by direct contact and meeting with the private and public sectors. And a case study approach has been considered to analyse the technical deficits of current practice of 3D registration in Victoria.
This paper firstly discusses different aspects of the 3D cadastre to understand the 3D cadastre needs and requirements. Then, current practice of 3D registration of land rights, restrictions and responsibilities is analysed in Victoria using a case study (an underground car park). Finally, a 3D cadastral demonstration is presented to illustrate practical issues for moving toward 3D cadastre.

2. ASPECTS OF 3D CADASTRE

3D cadastre would be a tool in a land administration system to spatially and three dimensionally register land rights, restrictions and responsibilities. 3D Cadastre should have the capability to capture, store, edit, query, analyse and visualize multi-complex properties and infrastructure objects in a defined and clear legal, institutional and technical framework with a documented set of standards. This section explores three aspects that should be considered when developing a 3D cadastre.

2.1 Legal aspects of 3D cadastre

3D property owners such as the owner of an apartment unit are entitled to use a specific 3D space. These 3D spaces are usually located on top of each other within one land parcel or sometimes extending over a number of land parcels. In most jurisdictions, owners of 3D properties share implicit rights in the common areas which are mostly managed by service companies and Owners Corporation. 3D property legislations, if exist, do not support a full 3D property representation in some jurisdictions. For example, establishment of 3D construction properties was not allowed in Norway or a division of ownership was not possible in the third dimension in Sweden (Stoter & Oosterom, 2006). To overcome this problem, legal systems in some countries, have to develop to support registration and representation of 3D properties.

For example, the property legislation had been developed in Victoria (Australia) over a long period of time to meet the demands for multiple ownerships of land and buildings because financial institutions would not accept such a 3D property as security for funding. Until the Subdivision Act 1988, different Acts and regulations had been introduced to legislate for owning and securing 3D properties (Figure 2), but all these have evolved to meet the needs of developers, owners, mortgagees and planners of 3D properties (Libbis, 2006; Paulsson, 2007).

The basic subdivision of land used to be carried out under the provisions of the now repealed Local Government Act 1958 and then be registered at the Land Registry under provisions of the Transfer of Land Act 1958 (Figure 2). This type of subdivision was inflexible in that it only allowed for the subdivision of land along defined horizontal boundaries on the ground. The Transfer of Land (Stratum Estate) Act 1960 provided a legislative framework for separate ownership of flats or other units. It enables title to be issued for each owner and a title for common areas which are owned by a service company. In the Strata Title Act 1967, separate titles were available for each unit. The owners corporation came into existence instead of the service company and is registered in the Land Registry with its details, rules, rights and responsibilities. Each owner is automatically a member of the owners corporation. Thus, dealing with the strata title was considerably less complex than stratum title. The Cluster Titles Act attempted to resolve the problem of staging and the progressive creation of common property, as well as to provide for pre-selling and to overcome constraints which applied to site requirements and the sharing of facilities. The Act promised future subdivisions that preserved special site features, such as trees or streams, and the provision of special interest developments, such as tennis courts or stables and horse tracks, but these expectations were not fulfilled. The subdivision system before the Subdivision Act 1988 was regarded as complex, costly and time consuming. The objectives of the Subdivision Act were to introduce a uniform process for subdivision approvals which are part of the planning system, a uniform style of title for property in Victoria, a system that is sufficiently flexible to allow for changes to be implemented from time to time, a system which has the municipal council as the central body responsible for the co-ordination of planning, building, traffic and drainage control, and a simplified Act which can more readily be understood by interested users and laymen, such as developers and members of the bodies corporate. The Land Act 1958 and the Property Law Act 1958 have been developed to subdivide Crown lands (Libbis, 2006; Paulsson, 2007).

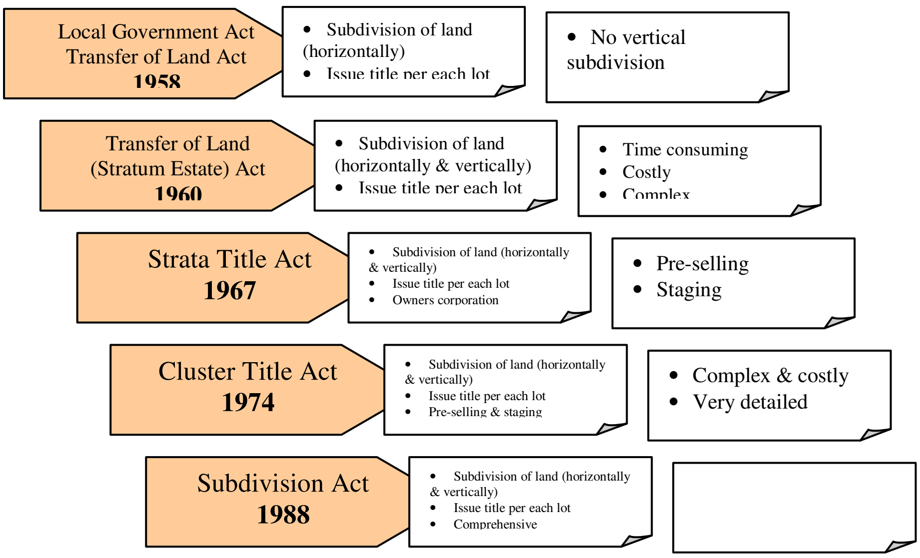

Figure 2 (a). 3D property legislation (Subdivision Acts) in Victoria for Freehold lands

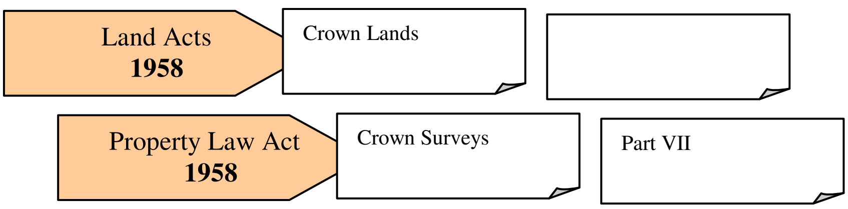

Figure 2 (b). Subdivision Act for Crown lands

Victoria's current legislation allows owners and developers to register the 3D properties; however, depicting 3D rights, restrictions and responsibilities is complex and difficult to be understood by the public.

2.2 Institutional aspects of 3D cadastre

Legal aspects lays the ground work for land administration, but cadastres are only meaningful if they operate within an institutional context, providing regulations for defining property rights, defining mechanisms for acquisition, etc., and defining tasks and responsibilities of the public administration empowered to register. This is equally true for 3D cadastre. Without defining the third dimension in property rights regimes, 3D cadastres are meaningless (Molen, 2003).

As shown in Figure 3, there should be a close and consistent relationship between public and private sectors to share knowledge and to reach a common viewpoint on the concepts and principles for the development of 3D cadastre.

Institutional aspects can be divided into different categories. Firstly, administrative institutions that execute and protect the regulations set by the legislations. This might include surveyor-general, registration body for cadastral surveyors, land registry, local government, association of developers, and association of Owners Corporation.
Secondly, conceptual institutions that provide a unified of 3D concepts such as, apartment, 3D ownership, 3D property, multi-storey building, high-rise building, complex building and so on.

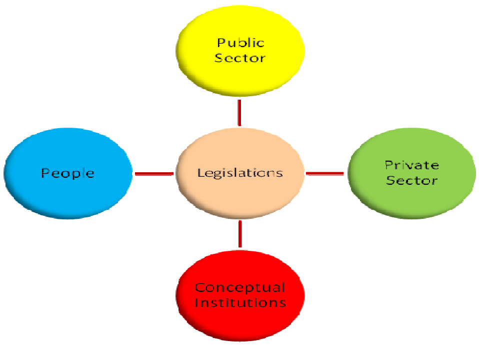

Figure 3. Relationship between organizations

In addition, legal and technical aspects can drive institutional aspects. For example, the Department of Sustainability and Environment (DSE) and the Department of Planning and Community Development (DPCD) are two separate departments with different responsibilities. DSE facilitates the land registration process and acknowledges subdivision plans and issues titles. DPCD assesses and issues planning approval for applicants. However, the SPEAR project created a platform for the two departments to two work with one system. SPEAR (Streamlined Planning through Electronic Applications and Referrals) project allows subdivision and planning approval applications to be compiled, lodged, managed, referred, approved and tracked online anytime. Therefore, it can be seen that technology and technical aspects drive institutional aspects as well.

2.3 Technical aspects of 3D cadastre

Technology in 3D cadastre is the use and knowledge of tools, models and methods to perform 3D cadastre. Progress in technology increases the efficiency of cadastre. Functionality of cadastre develops in accordance to progress in computers and data capturing methods (Table 1).

Table 1. 3D cadastre development

Time	Available Technology	Aims of Cadastre	Possibility of 3D Representation
Before 1980s	Paper	Registration, Fiscal, 2D Visualisation	N/A
1980s	CAD	Registration, Fiscal, 2D Visualisation	N/A
1990s	CAD, GIS	Registration, Fiscal, 2D Visualisation, 2D Vector-based Analysis	N/A
2000s	CAD, GIS, 3D Raster-based Tools	Registration, Fiscal, 3D Raster-based Visualisation, 2D Vector-based Analysis	Yes
2010	Augmented reality Virtual reality	Registration, Fiscal, 3D Vector-based Visualisation, 2D Vector-based Analysis	Yes
Future	3D (CAD, GIS), 3D DBMS 3D Vector-based	3D Registration, Fiscal, 3D Visualisation, 3D Vector-based Analysis	Yes

While cadastral systems were paper based, they were used for a limited applications such as land inventory and taxation purposes (Ting & Williamson, 1999). Nowadays, GIS and other spatial analytical systems put more applications on cadastral systems and it is possible to analyse and query cadastral data. Although all efforts on cadastral system were previously 2D, new initiatives such as Google Earth, Google SketchUp, Autodesk Map 3D, Bentely's City GIS, and Esri's ArcGIS are promoting researchers to consider the practical possibilities of 3D cadastre. Inevitably, 3D cadastre will be achieved by developing 3D CAD, 3D GIS, and 3D DBMS which will provide possibility of drawing, updating, analysing and visualising 3D cadastral objects and 3D spatial ownership of land rights, restrictions and responsibilities which is completely independent of 2D land parcels with a geometrical and topological structure in both raster and vector based format.

In addition, it should be noticed that, current 2D cadastral data is essential and was expensive to acquire in both time and money. Therefore, it is important to utilise current cadastral data in 3D cadastre developments.

Technical aspects of 3D cadastre vary by content and can be categorised into different subjects based on their objectives (Figure 4):

- 3D data capturing: researching on what types of 3D cadastral objects need to be collected (buildings, pipelines, tunnels, etc.) and what methods of 3D data capturing can be used to capture 3D data (land surveying, aerial photogrammetry, laser scanning, etc.). Integration of different 3D data capturing methods is one solution in this research area, while cross-sections are being used to determine vertical aspects of 3D cadastral objects.

- 3D data representation: Visualising 3D cadastral objects, 3D analyses and 2.5D earth surface in vector and raster formats. 3D GIS and CAD systems can provide this opportunity. 2D paper based plans are being used to represent 3D data in most cadastral systems.
- Cadastral updating: updating cadastral objects in DCDB. Geometry and topology of 3D cadastral objects are complex and they need to be maintained in a 3D DBMS. Currently 2D DBMSs are being used for 3D cadastre.
- 3D data modelling: developing data models to identify 3D objects and their relationships. 3D cadastral data modelling will enable the capture, manipulation, analysis and visualization of 3D land rights, restrictions and responsibilities. Most of the existing cadastral data models are 2D, such as the ePlan data model (ICSM, 2009) which is restricted in its cover to a few 3D objects such as volumetric lots.

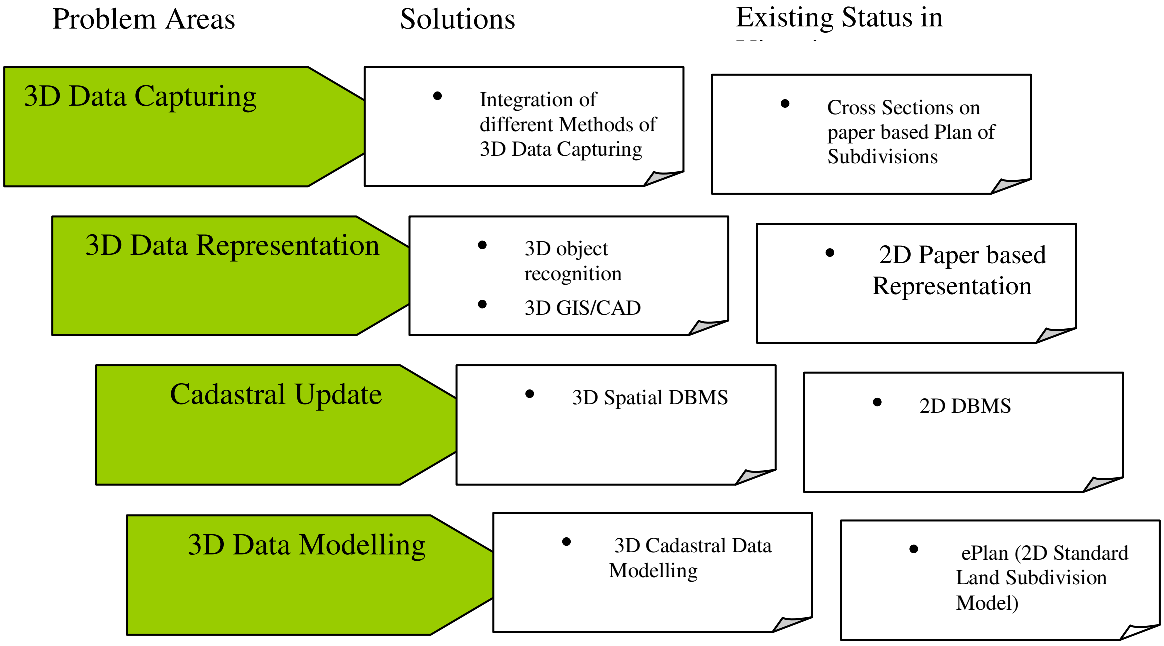

Figure 4. Technical problem areas in 3D cadastre

3. CURRENT PRACTICE OF 3D REPRESENTATION IN VICTORIA

Victoria's land administration system typically comprises the following components providing the different 2D spatial and non spatial information (Williamson, 2003):

- Textual Component: the land register identifies real property parcels, which includes all land parcels and identifies owners' rights, restrictions, and responsibilities, ownership, easements, mortgages etc.
- Spatial Component: the cadastral maps show all land parcels graphically corresponding to the registered title with plan numbers and unique identifiers. Cadastral maps consist of fixed and general boundaries, about 90% and 10% respectively.

The plan of subdivision contains drawings that show the layout of the lots (land, building, air space) and provide all necessary information about the development such as easements and restrictions (covenants) (Libbis, 2006). In a plan of subdivision, cross-sections must be shown on the plan when any parts of the lots, common property, roads or reserves are located above or below other parts ("Subdivision (Procedures) Regulations," 2000). These cross-sections show the upper and lower limits of parcels, on which storey or level the parcels are situated, and stairs, balconies or other features where appropriate. The selection of what type of side view (or elevation) is shown is dependent on both circumstances and personal preferences. There must be sections, elevations or diagrams to fully define overlaps in three dimensions (Paulsson, 2007). It can be concluded that 3D property information is reflected in plans of subdivision in the Land Registry, but they are not represented in cadastral maps and the DCDB. Although for tunnels and bridges, Land Victoria provides a limited presentation of 3D data in the DCDB. A classic example of this presentation is the CityLink infrastructure in Melbourne.

The digital cadastral map in Victoria is based on land parcels. Properties above or below ground level are not recorded in the cadastral map. However, tunnels and other underground structures might be recorded in the cadastral map. As can be seen in Figure 5 (a), the southern part of the University of Melbourne city campus (University Square) is surrounded by buildings and also has an underground car park. The digital cadastral map (Figure 5 (b)) represents two dimensional information. This is part of a case study to identify the issues around 3D property registration and representation.

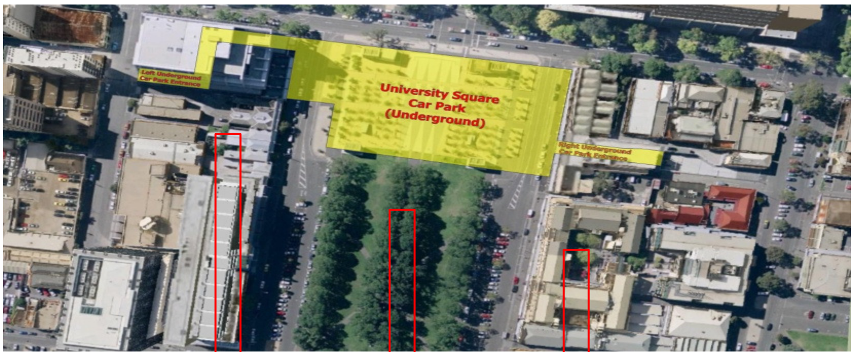

Figure 5 (a). Location of underground car park in University Square (Google, 2010)

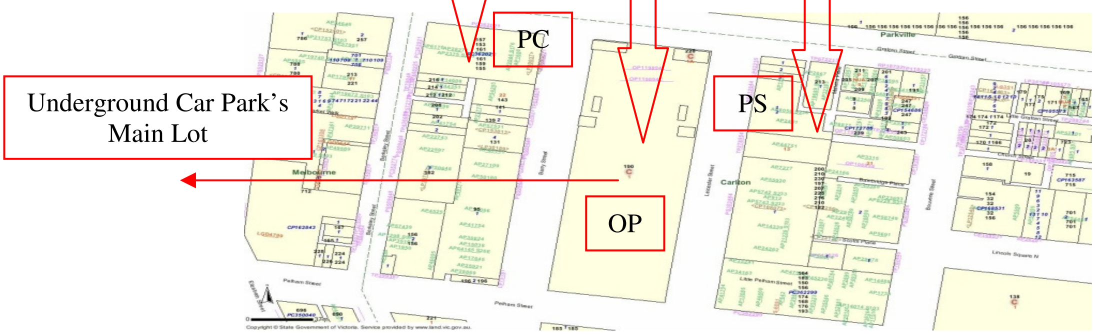

Figure 5 (b). Cadastral map of University Square (LandVictoria, 2010)

Figures 6 (a), (b), and (c) show plans of survey of the underground car park, which is a Crown land (OP), the location of cross-sections (Figure 6 (b)), and diagrams of cross-sections (Figure 6 (c)). The Australian Height Datum (AHD) is used to measure vertical dimensions. With regards to Figure 6 (c), elevations of ceilings and rooves are known, where cross-sections are located. Although 3D information is reflected in the plans of subdivision, it is limited to some parts of that and restrictions and conditions are described in the text format and are not fully spatially represented. The problem will be exacerbated if the 3D property has a complex shape where the cross-sections cannot clearly represent the complex building shape.

The lots in a subdivision are defined by their boundaries. These lots can consist of land, airspace, buildings or a combination of these. A plan of subdivision must contain a diagram showing these types of lots. The boundary between a lot unit and the common property is usually defined as the inner surface of the unit, which means that the owner is responsible only for the inner cubic space and interior surfaces of the unit, and the Owners Corporation has clear responsibility for everything beyond this. Other options for the boundary are the median or external face of walls. The developer, Owners Corporation manager and surveyors make decision to determine where the boundary should be located.

However, there must be a notation on the plan which unambiguously defines the location of all boundaries defined by the buildings, such as inside face, outside face, median, etc. There is no set method of describing the location of boundaries. The location is dependent on circumstances and the preferences of the surveyor and client. There are, however, some typical notations that are commonly used, for instance for the location of boundaries defined by buildings, where the median for boundaries is marked “M”, the exterior face for boundaries marked “E” and interior face for all other boundaries (refer Figure 6(a)).

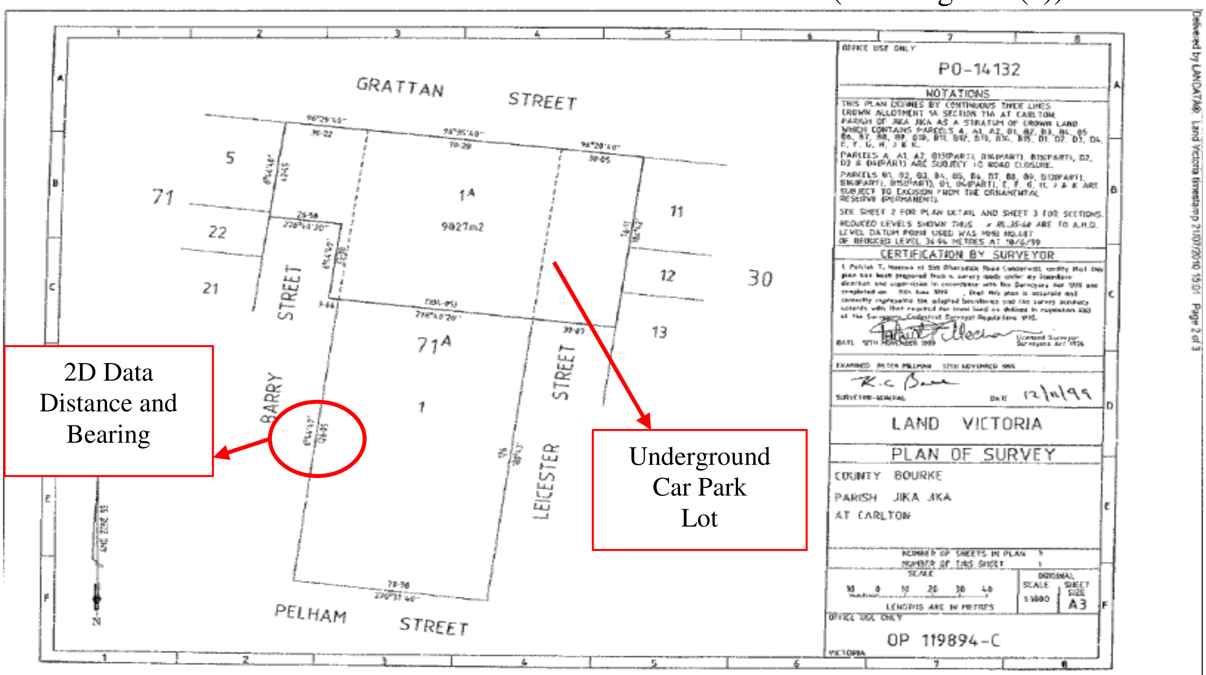

Figure 6 (a). Plan of Survey with 2D data- Sheet 1

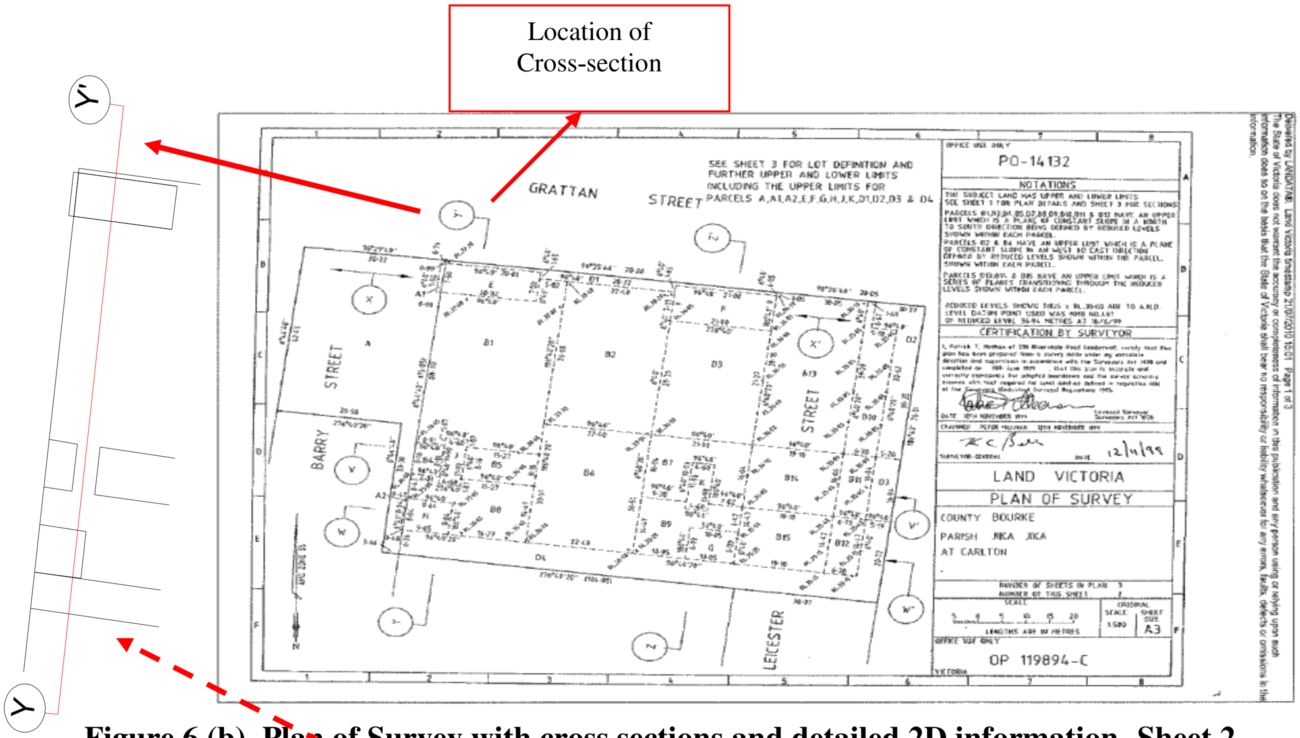

Figure 6 (b). Plan of Survey with cross sections and detailed 2D information- Sheet 2

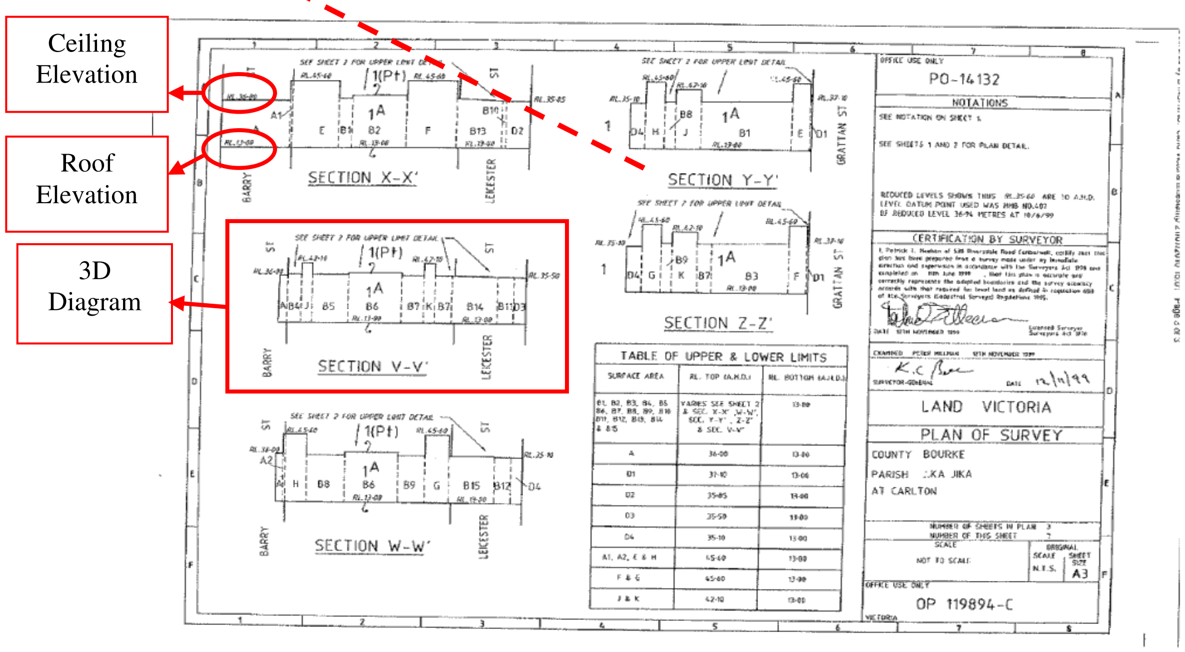

Figure 6 (c). Cross Sections on plan of survey- Sheet 3

The west entrance of underground car park passes under the Allan Gilbert building which belongs to the University (shown at top left in figure 5 (a)), and has a plan of consolidation (PC). Since it is a plan of consolidations, it contains only 2D survey information. Easements and restrictions are not represented in the plan and they are written as text in the notation section of the plan. There is no below ground information or underground entrance details on the plan.

The east entrance of the underground car park passes under another building, which has a plan of subdivision (PS). This plan has four sheets and only represents the 3D information of the building located on the east underground entrance. In the first sheet, easements, restrictions and textual information have been written as text in the notation section of the plan. In the plan of subdivision, 2D survey information is presented for the lower ground level. Cross-sections are also shown on this sheet. The location of an easement has been depicted in sheet 3 for the basement level. Cross-section diagrams have been drawn on sheet 4. There is no vertical information for the east entrance of the underground car park and easements and restrictions have not been spatially presented.

As it is clear, current practice of 3D representation requires further improvement to adequately and effectively represent 3D properties. In the following section, complexities of the current method have been assessed to emphasise the need for 3D cadastre.

3.1 Assessment of current practice of 3D representation in Victoria

As a result of analyzing the current practice of 3D representation in Victoria in the previous section, there are many complexities that are identified in the different plans in terms of 3D and vertical information such as:

- Vertical information only exists in the cross-sections diagrams.
- The location of cross-sections depends on the surveyor's decision and does not conform to a standard.
- The height of ceiling and floor levels are determined in the cross-sections diagrams.
- Lack of continuity between subdivision plans of adjacent lots (west and east car park entrances are not included in the car park subdivision plan and the information is only available from other plans that do not continuously match).
- The plans are paper based and cannot adequately represent the 3D structure.
- It is difficult to determine and measure dimensions, area and volume from these plans.
- Many pages are required to depict a simple 3D property.
- Interpretation of these plans is complex and time consuming and requires expertise.
- The plans do not support additional non-spatial information such as textures and colours.
- 3D analysis is not possible on paper plans.
- Some rights, restrictions and responsibilities cannot be spatially represented in the plans.

Overall, 3D plans of subdivision require improvements to represent the actual 3D situation. Although this 3D registration method is effectively being used to register and secure 3D properties in Victoria, the 3D cadastre can improve, represent and manage 3D properties, in addition to 3D visualisation possibilities. 3D analysis also would operate on 3D data to perform different applications.

3.2 Developing a 3D cadastre on the case study

In order to illustrate the complexity of 3D property registration and representation, a demonstration has been developed on the case study (University Square) to illustrate 3D cadastre concepts in some steps (Figure 7). The demonstration can clarify what expectations are satisfied, what facilities can be provided, what problems can be solved, and what applications can be applied by a 3D cadastre.

Plans of subdivision for the University Square underground car park have been collected as the first step of developing the 3D cadastre demonstration. Engineering plans have been also used to collect more information. Since the nature of all these plans is 2D, they cannot cover the 3D reality adequately. Direct measurements have been taken to capture the required spatial data. Digital photography has also been used to collect non-spatial information such as the texture and colour of different parts of the car park to allow the demonstration to depict the actual structure. Google SketchUp, Google Earth, AutoCAD Map 3D, ESRI's ArcScene have been used to build vector and raster data and to develop the demonstration.

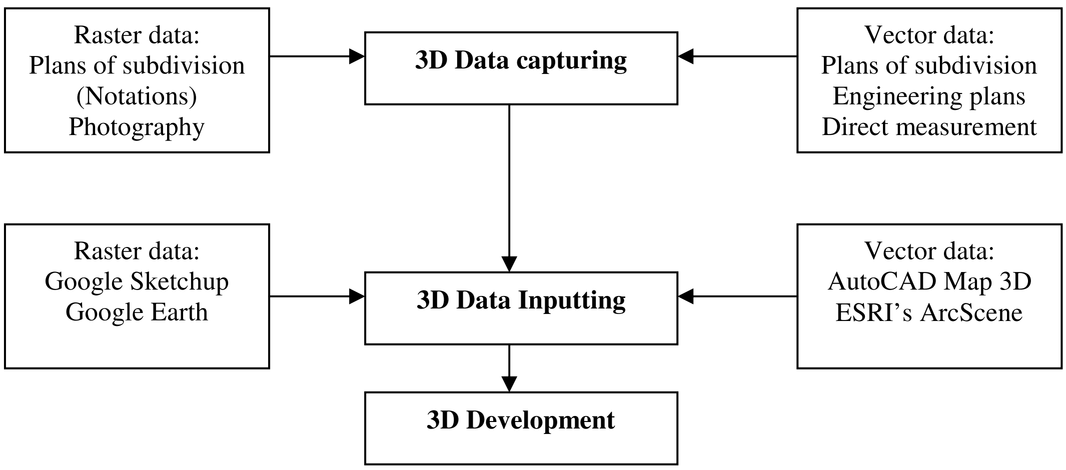

Figure 7. 3D cadastre demonstration development

The demonstration (Figure 8) represents the actual structure and shows all aspects of its 3D properties. However, it is more important to represent 3D spatial land ownership rights, restrictions and responsibilities within the actual structure which will be added in the demonstration.

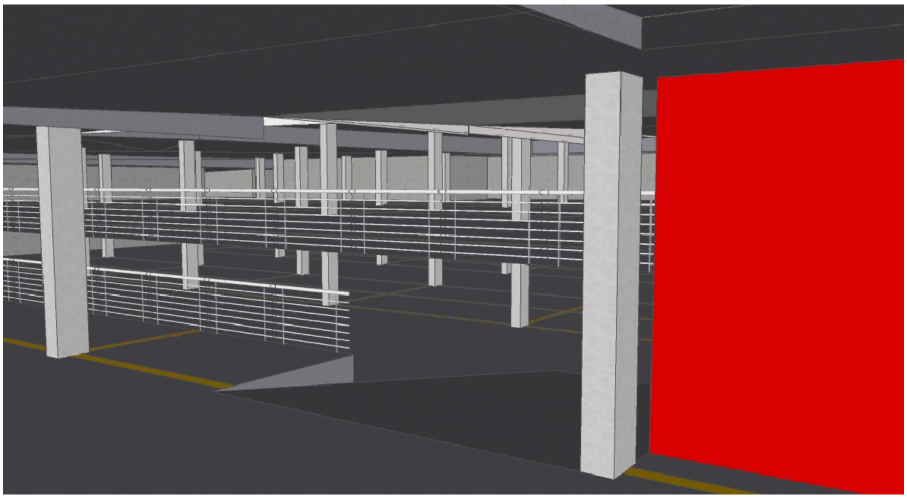

Figure 8. A snapshot of 3D cadastre demonstration of underground car park

4. CONCLUSION

Our natural surrounding is 3D. Population growth and urbanization lead to the use of urban spaces both horizontally and vertically by constructing 3D properties such as apartments and high-rise buildings. In the more densely populated cities, underground development and infrastructure facilities occupy underground spaces. The concept of land ownership rights, restrictions and responsibilities is 3D. Consequently, land administration systems should be equipped with 3D cadastre to support 3D challenges, if it would ensure sustainable development.

This paper discussed that legal, institutional, and technical aspects of 3D cadastre should be considered in 3D cadastre development for each jurisdiction. Legal support to register and represent 3D properties (legal aspect), institutional support to establish relationships between involved parties (institutional aspect), and technical support to realise 3D cadastre (technical aspect) are basis for 3D cadastre development.

Victoria has the potential to accommodate a 3D cadastre. Victoria's property legislation allows registering of 3D properties and related institutions already have an established close relationship to allow for the development of 3D cadastre; and available 3D technologies provide opportunities to implement 3D cadastre in Victoria.

Progress and development of 3D property legislation meet the demands for 3D registration in Victoria and they forced the representation of the third dimension by using cross-sections on the paper-based plans of subdivision. There is a unanimous opinion and movement toward the development of the 3D cadastre by the public and private sectors. However, there remain some obstacles to developing and implementing the 3D cadastre from the technical point of view. According to the assessment of the case study (the underground car park), provided information insufficient to produce 3D objects. Vertical information does not exist in all subdivision plans. Non-spatial information such as colour and texture of walls cannot be identified by these plans. Consequently, there is not a sufficient technical potential to develop and implement 3D cadastre in Victoria.

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BIOGRAPHICAL NOTES

Ali Aien started his PhD on 3D cadastre in 2010 at the Centre for SDIs and Land Administration at the Department of Geomatics, the University of Melbourne. This research investigates the development of 3D cadastres. The research aims to develop and implement a data model to enable the capture, storage, editing, querying, analysis and visualization of 3D land rights, restrictions and responsibilities in cadastre. Ali currently is a member of 3D-Cadastres- Work plan 2010-2014. He also has a bachelor degree in surveying engineering and master degree in GIS engineering.

Abbas Rajabifard is an Associate Professor and Director of the Centre for SDIs and Land Administration at the Department of Geomatics, the University of Melbourne. He is President of the GSDI Association, a member of ICA-Spatial Data Standard Commission, and a member of Victorian Spatial Council.

Mohsen Kalantari is a Research Fellow at the Centre for SDIs and Land Administration at the Department of Geomatics, the University of Melbourne working on 3D cadastre and spatial metadata automation. He was previously involved in the CRC project for the assessment of metadata entry tools and their fitness for ANZLIC requirements. Mohsen currently is also the ePlan project coordinator at Land Victoria, Department of suitability and Environment and is a member of the ICSM ePlan working group. He finished his PhD from the University of Melbourne in 2008. Mohsen has a bachelor degree in surveying engineering and master degree in GIS engineering.

Ian Williamson is both a professional land surveyor and chartered engineer who is Professor of Surveying and Land Information at the Centre for Spatial Data Infrastructures and Land Administration, Department of Geomatics, University of Melbourne, Australia. His expertise is the cadastre, land administration, and spatial data infrastructures.

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