Moving Towards a Fully Operational 3D Digital Cadastre: Victoria, Australia

Davood SHOJAEI, Hamed OLFAT, Abbas RAJABIFARD, Mohsen KALANTARI and Mark BRIFFA, Australia

Key words: 3D digital cadastre, roadmap, Victoria, Australia, land administration, ePlan.

SUMMARY

Population is growing and due to urbanisation, cities are expanding horizontally and vertically to accommodate more population. Managing these crowded cities with many high-rises and infrastructures below and above the ground surface requires efficient systems. However, the current land and property registration systems mainly use two dimensional (2D) approaches to manage below and above the ground spaces. The current methods of registering land and property (in form of paper and PDF plans) are not sustainable, and efficient registration methods are required to cater for current and future needs.

To this end, the Intergovernmental Committee on Surveying and Mapping (ICSM) has developed a strategy[1] for modernising the Australian Cadastre to support a 3D, accurate and digital cadastre by 2034. This strategy has a vision to develop a cadastral system that enables the interested community to readily and confidently identify the location and extent of all rights, restrictions and responsibilities (RRRs) related to land and real property.

Following the ICSM strategy, land authorities in Australia are now reforming their cadastral systems to support accurate and 3D digital cadastral data. The cadastral reform requires a detailed roadmap to define both short and long-term visions and relevant milestones, projects and timeframes.

Accordingly, Land Use Victoria (LUV), the land authority in the State of Victoria, Australia, has started to develop a roadmap for implementing a digital cadastre through collaboration with the Centre for Spatial Data Infrastructures and Land Administration (CSDILA[2]) at the University of Melbourne. The following short and long-term visions have been defined as part of this roadmap:

- Short-term vision: Provide the infrastructure and services to enable the submission and registration of digital data (ePlan) for all 2D cadastral plans by 2020.
- Long-term vision: Implement ePlan for 3D cadastral plans by 2025.

[1] www.icsm.gov.au/publications/cadastre-2034-strategy
[2] www.csdila.unimelb.edu.au/

The short-term vision is mainly concerned with supporting all 2D plan based applications in digital format (ePlan). As part of this vision, LUV has considered an interim approach to support strata plans. In this approach, the land parcel will be captured digitally in ePlan and the building itself will be displayed on PDF plans. This approach would continue until the long-term vision is realised.

A key component of the long-term vision is supporting strata plans in digital format. To achieve the long-term vision, LUV commenced resourcing the research into designing and implementing a 3D digital cadastre in 2014, focusing on providing more efficient and effective services to the land and property industry. Over the past four years, among the technical, legal and institutional aspects of a 3D digital cadastre, the focus has mainly been on investigating the technical aspects including 3D data visualisation, validation and modelling to support strata plans in ePlan. The legal and institutional aspects have not yet been researched.

To support the implementation of the Victorian digital cadastral long-term vision, the research teams at LUV and the University of Melbourne have started to investigate and plan the research and development programs for achieving a full 3D digital cadastre by 2025. The outcomes of this investigation including roadmap development methodology, the progress to-date, and timeframes will be discussed in detail in this paper.

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1. INTRODUCTION

Due to the increase in population and high demand for land in urban areas, the current method of urban development is extending the land above and below the ground. However, the traditional two-dimensional (2D) land management systems cannot efficiently manage complex three-dimensional (3D) spaces and they are becoming more limited for handling complex scenarios in urban areas. Therefore, a 3D digital cadastre is required to address these limitations.

Although, many researchers have been investigating the implementation of a 3D digital cadastre, there is currently no existing 3D digital cadastre fully operational in the world. One reason is the lack of integration among these research activities that works towards an operational 3D cadastral system. Accordingly, a roadmap is required to align and integrate these research activities in a way to achieve a 3D digital cadastre.

Recently, the Intergovernmental Committee on Surveying and Mapping (ICSM) developed a strategy for modernising the Australian Cadastre to support a 3D, accurate and digital cadastre by 2034. This strategy has a vision to develop a cadastral system that enables the interested community to readily and confidently identify the location and extent of all rights, restrictions and responsibilities (RRRs) related to land and real property.

Therefore, some jurisdictions in Australia have begun to review their cadastral systems to move to a digital cadastre. Land Use Victoria (LUV), the land registry in the State of Victoria, Australia, commenced investigating various aspects of a 3D digital cadastre including the legal, technical and institutional aspects. Various topics including visualisation (Shojaei *et al*., 2013), data modelling (Shojaei *et al*., 2016) and validation (Shojaei *et al*., 2017b) of 3D property units have recently been investigated at LUV. However, there is no guideline available to define the priority of the projects, connection between them, and the input and output of each research project. Therefore, there is a need to have a roadmap in Victoria to achieve a 3D, accurate and digital cadastre.

Due to the importance of this topic, LUV has commenced developing a roadmap for implementing a digital cadastre through collaboration with the Centre for Spatial Data Infrastructures and Land Administration (CSDILA[3]) at the University of Melbourne by working towards the short and long-term visions.

According to the short-term vision, all 2D plans must be supported by 2020 as part of the ePlan project in a digital format. Presently, some of these 2D plan based applications can be

[3] www.csdila.unimelb.edu.au/

submitted in ePlan LandXML format. A key component of the long-term vision is supporting strata plans in ePlan. To achieve the long-term vision, LUV commenced investigating a 3D digital cadastre in 2014, focusing on providing more efficient and effective services to the land and property industry. Over the past four years, among the technical, legal and institutional aspects of a 3D digital cadastre, the focus has been on investigating the technical aspects including 3D data visualisation, validation and modelling to support strata plans in ePlan. The legal and institutional aspects have not yet been researched.

To support strata plans in ePlan, the research teams at LUV and the University of Melbourne have started to develop a roadmap for achieving a fully operational 3D digital cadastre by 2025 by defining 3D digital cadastre milestones, projects, and timeframes. To develop this roadmap, a methodology with four phases was applied which is discussed in this paper.

This paper is structured as follows: In Section 2, we review the existing roadmaps for implementing a 3D digital cadastre in the world. Then, the Victorian cadastre is introduced in Section 3. Section 4 discusses the methodology and the progress to-date of the roadmap development and the paper concludes in Section 5 with a conclusion and future directions.

2. LITERATRE REVIEW

Coordinated and organised by FIG, there has been a significant amount of research and development into a 3D digital cadastre. These efforts include research and development in the technical aspects of a 3D digital cadastre, and the legal and institutional perspectives. There is ample body of knowledge that potentially assists countries in the world to select the right tools to implement a 3D digital cadastre. Having said that there is a lack of a framework that supports long-term planning, by matching tools with the objectives of 3D digital cadastre goals. A framework that provides a roadmap can prioritise the implementation of 3D digital cadastre considering all the dependencies between technical, legal and institutional challenges. The framework is critically concerning the engagement with stakeholders that will be impacted by the introduction of a 3D digital cadastre.

The current body of knowledge includes examples of 3D real property definitions and various models adopted to manage 3D RRRs. The experiences of countries in Europe, America, Middle East and Oceania are presented, and different regulatory frameworks are discussed (Kitsaki *et al*., 2018). 3D parcels, as the basic building block of a 3D cadastre are also examined with a focus on the initial registration of a 3D digital cadastre (Dimopoulou *et al*., 2018). Technologies such as data formats, visualisation engines, and databases are available to assist with moving from an analogue 3D cadastre to a digital environment. Data models for implementing a 3D digital cadastre guided by the LADM is also widely explored and experimented. More recent developments in a 3D digital cadastre favour building-based data models such as IFC to city-based data models such as CityGML (van Oosterom *et al*., 2018). There are still gaps in the database management systems that specifically cater for cadastral data (Janečka *et al*., 2018). Visualisation of 3D cadastral information have also been identified as a critical matter as the end user of a 3D digital cadastre will need an effective medium to comprehend the complexity of multi-storey development above and underground (Pouliot *et al*., 2018).

Kalantari *et al*. (2015) proposed a framework comprising organisational motivation, institutional arrangements, information interpretation, information organisation, involvement governance and capacity building as key factors when developing roadmaps in upgrading cadastral information systems.

Kalantari and Rajabifard (2014) undertook an empirical research to identify stakeholders in the land development process in order to present a general roadmap for the implementation of a 3D digital cadastre. Their study involved developers, land surveyors, building managers, urban planners, local governments and land registration systems. The research was undertaken as a case study in Victoria through which 50 experts were interviewed with a particular focus on high-rise buildings. Through the study, there are three milestones identified for a roadmap. As a 3D digital cadastre is complex and multifaceted, undertaking that involves several stakeholders, it is critical to frame a boundary and define the scope of it. The boundary is generally based on the willingness of the stakeholders as well as the capacity to upgrade land administration system. The second milestone proposed by this research spans around the leadership and that is the body or organisation that leads the development of a 3D digital cadastre. The research also highlighted that this leadership should put emphasis on the role of serving industry and the opportunities a 3D digital cadastre may bring about. The third milestone proposed is the development of the technical requirements highlighting the role of the stakeholders as well as developing the capacity of the jurisdiction with regard to the maintenance of a 3D digital cadastre.

In the next section, the current status of the cadastre in Victoria is reviewed.

3. VICTORIAN CADASTRE

The Victorian cadastral information has transitioned from paper to digital over time, as illustrated in Figure 1. Before the 1990s, cadastral plans were all lodged in paper. Vicmap Property, the State Digital Cadastral Database (DCDB), was created in the early 1990s from the digitisation of paper-based map records held by Melbourne Water (metropolitan area) and the State Government (rural area). Vicmap Property comprises more than 3 million land parcels and associated property attributes, such as lot and plan number, and crown description, in the State of Victoria.

Land title information was migrated from paper to the Victorian Online Title System (VOTS) in 2000. VOTS contains a record of all Victorian titles registered under the Torrens System (Victorian Torrens Title, 2018). The system is maintained by LUV and is used to accept, create and register land transaction lodgments, and to update land holdings and registered interests on title as well as create new titles.

Prior to the launch of the Surveying and Planning through Electronic Applications and Referrals (SPEAR) pilot in 2004, subdivision applications could only be processed via paper.

This was generally a lengthy and protracted process that was initiated by the surveyor, on behalf of their client (developer). The process and application milestones are well defined by the Planning and Environment Act 1987 (Victorian Government Planning and Environment Act, 1987) and Subdivision Act 1988 (Victorian Government Subdivision Act, 1988), however achieving these milestones, in a paper environment, where there are multiple stakeholders involved in the decision-making process led to delays, errors, and poor transparency between the interested parties.

Although there was a lot of scope to improve efficiencies throughout the life of the application, there was no means of implementing these changes for the benefit of all parties, due to the technology constraints of a pre 'world wide web' era.

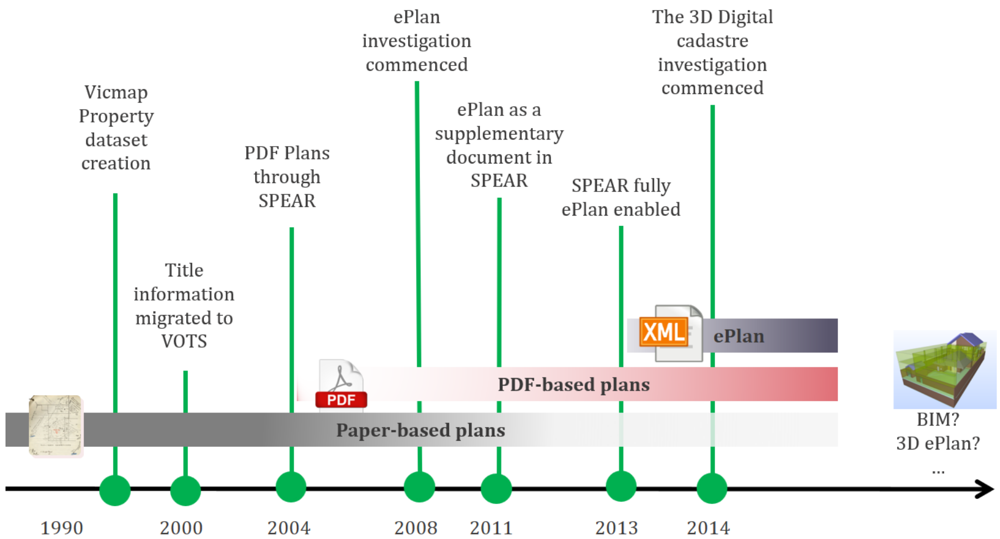

Figure 1. Victorian cadastral information (paper → digital) (Olfat *et al.*, 2018)

SPEAR revolutionised the way subdivision applications were handled, by introducing online end-to-end processing and tracking of plan applications from their initial submission with local government, right through to registration at LUV. A surveyor can use SPEAR to apply for any plan-based dealing under the Subdivision Act 1988, and the planning permit to subdivide under the Planning and Environment Act 1987.

According to Figure 1, the investigations to the ePlan project commenced in 2008 in Victoria. ePlan, as a digital cadastral data initiative, is a collaborative program between the land authorities and the surveying industry which aims to replace paper and PDF cadastral plans and surveys with digital data. LUV collaborated with the ICSM ePlan Working Group on developing a national data model to cover all Australian jurisdictions' cadastral and survey requirements. In 2011, SPEAR enabled surveyors interested in ePlan to upload an ePlan LandXML file (adopted ePlan format) along with their PDF application. From 2011 to 2013, ePlan was piloted in Victoria by LUV, the surveying industry and software vendors. In May 2013, SPEAR incorporated ePlan services including visualisation, validation, and data download, which are briefly discussed below (Olfat *et al.*, 2017):

- ePlan Visualisation Service - This service converts the ePlan LandXML file into PDF. The PDF plan forms part of the legal title in Victoria. The automatic visualisation of an ePlan file is fundamental in streamlining the processes and dissemination of digital cadastral data.
- ePlan Validation Service - This service identifies errors and potential problems in plans at an early stage of preparation and allows surveyors to correct these issues prior to the LUV examination process. This will result in a reduction in the number of refusals and requisitions received by surveyors. SPEAR currently has 130 ePlan validation rules which cover four main areas, the 'ePlan schema compliancy', 'survey accuracy (e.g., parcel area, parcel observations closure)', 'survey examination rules (e.g., appropriate title connections)' and 'metadata completeness (e.g., easement purpose)'.
- ePlan Data Download Service - This service is available through the LASSI-SPEAR application. LASSI-SPEAR is a web mapping application that allows users to search and download survey information. The digital data download service allows users to draw a polygon on the Mapbase (i.e., Vicmap Property) and download a digital file in ePlan LandXML format that contains parcel line works, administrative areas, datum, location addresses, road abuttals, survey marks and monuments. The downloaded ePlan file can be imported into surveying software packages to pre-populate the data for ePlan preparation, a saving for the surveyor.

Currently, three software vendors including LISTECH, Civil Survey Solutions and Geocomp Consulting support the Victorian ePlan in their respective software packages namely LISCAD, Stringer ePlan and ePSALON.

All 2D plans under the Subdivision Act 1988 are supported in ePlan. However, strata plans (building subdivision plans) which include overlapped ownership rights are not yet supported. As shown in Figure 2, building boundaries in subdivision plans in Victoria do not include dimensions (bearing, distance and height) to show the extent of building structures (Victorian Consolidated Regulations, 2011).
As indicated in Figure 1, the investigations around the 3D digital cadastre to support the building subdivisions in ePlan format commenced in 2014. Among the technical, legal and institutional aspects of a 3D digital cadastre (Aien *et al.*, 2012; Shojaei, *et al.*, 2017a), the focus has mainly been on investigating the technical aspects including 3D data visualisation, validation and modelling to support building subdivision plans in ePlan (Shojaei et al., 2016; 2017a; 2017b). The legal and institutional aspects have not yet been researched.

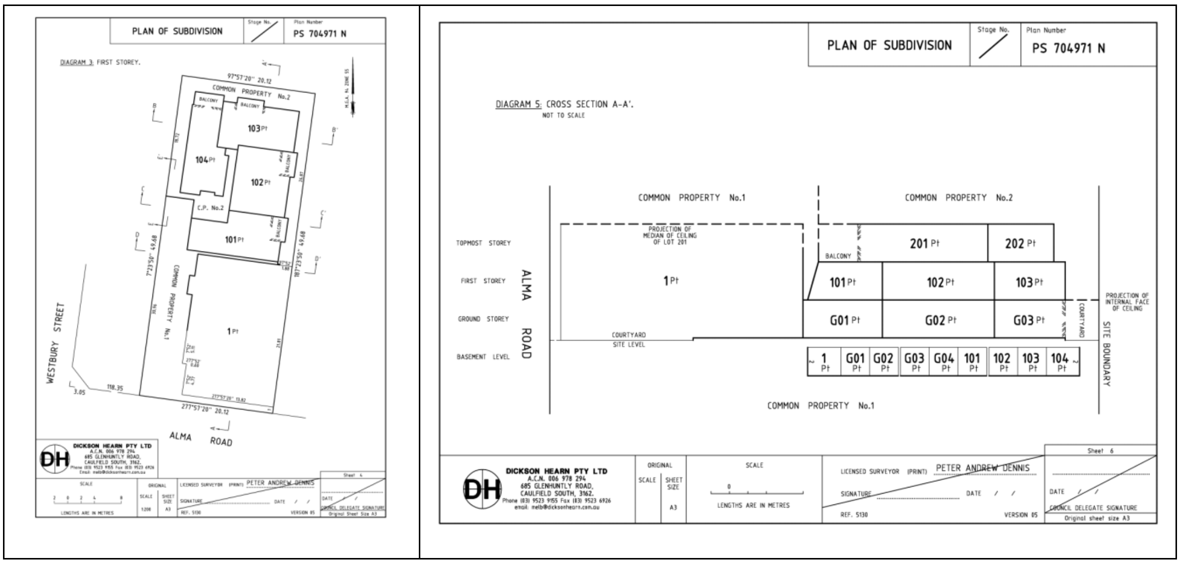

Figure 2. A building subdivision plan in Victoria including floor plans and cross-sections (Shojaei, et al., 2016)

The next section addresses the methodology for developing a 3D digital cadastre roadmap in Victoria.

4. ROADMAP DEVELOPMENT

A roadmap is a strategic plan which identifies the steps that an organisation should take to achieve the defined goals (IEA, 2014). This roadmap should include projects and actions to take in the defined timeframes, which can be short or long-term activities. In addition, the progress of a project towards the goals would be assessed using some methods which is addressed in the roadmap.

Before proceeding to develop a roadmap for a 3D digital cadastre, it is critical to determine whether such a roadmap would in fact be valuable or required for Victoria. This can be done by assessing the situation with regard to current cadastre.

A roadmap development process engages participants to develop an initial plan, and this roadmap also evolves when the document is finalised. Typically, roadmaps are updated periodically (e.g., every two to five years). The frequency of updating a roadmap is related to the time frame defined in the roadmap (IEA, 2014).

The following sections discuss the current approach in Victoria for developing a roadmap and the results achieved thus far as part of this development.

4.1 Development Process

The roadmap development process identifies goals and defines required actions towards a goal or vision. The process includes four phases to accomplish according to the approach proposed by (IEA, 2014). Figure 3 shows a snapshot of this roadmap.

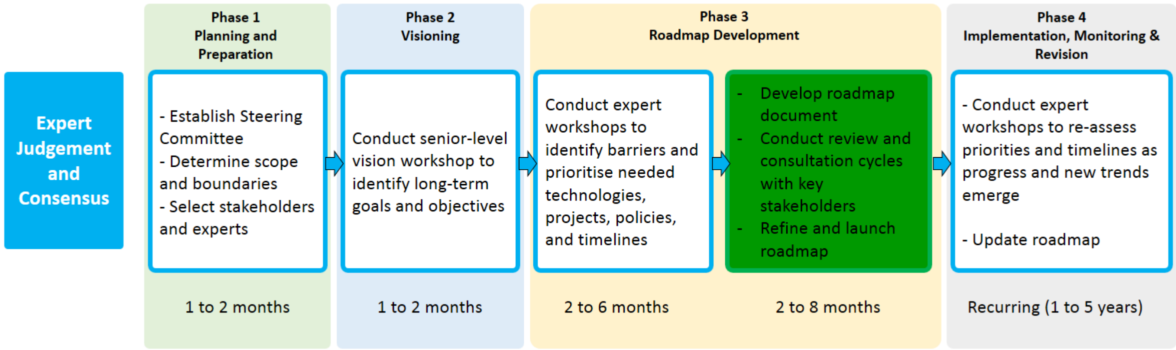

Figure 3. The development process of a 3D digital cadastre roadmap (adopted from (IEA, 2014))

According to Figure 3, expert judgement and consensus-building activities are the core of a roadmap development process, which are conducted through workshops. In these workshops, a cross-section of experts in technology, cadastre, and land administration have been gathered to develop the roadmap, define goals and milestones, recognise gaps, priorities tasks and projects. Developing consensus among experts involved in the development phase generates support for the roadmap and reduces the possible gaps in technology or policy. The four phases for developing the roadmap is described below:

4.1.1 Phase 1: Planning and preparation

This phase has three main steps including:

- -Establishing the steering committee
- -Determining scope and boundaries
- -Selecting stakeholders and experts

In each of these steps, various questions from participants will be raised and discussed internally and externally to start developing the roadmap. In addition, leaders in the industry can be engaged to verify the projects, goals, and visions.

4.1.2 Phase 2: Visioning

This phase sets the vision for determining the path towards implementing a 3D digital cadastre. Through a workshop, long term goals and objectives are determined with leading experts to discuss the desired future state of the cadastre. This can be achieved by looking at expected results in a specific time to discuss what future states are possible or required.

4.1.3 Phase 3: Roadmap development

After finalising the vision, the roadmap is developed by defining the required projects according to the experts' judgement to define activities, priorities, and timelines to reach the vision. For achieving this, several workshops are required to get experts to brainstorm and analyse the tasks.

According to the discussions and workshops, an initial version of the roadmap is drafted in a document. This document needs to be reviewed by all experts in the team. A comprehensive review process can significantly improve the quality of the roadmap, and identify the issues in the design. After an internal review, an external review by inviting wider audience participation and engagement can be introduced in the development of the roadmap. External reviewers can verify and support the roadmap to assure it is complete, accurate, and ready for publication (IEA, 2014). Then, it will be shared to the intended audience.

4.1.4 Phase 4: Roadmap implementation and adjustment

In the phase 3 of the roadmap development process, the roadmap is launched. Now, in the final stage, the roadmap is implemented and reviewed. The roadmap defines a set of research projects, implementations and tasks in a defined timeframe. Reviewing the roadmap is always required to assure it is aligned with the latest technology and requirements. Defining some indicators can measure the progress of the roadmap implementation. Workshops are also required to review the feedback received from the audience and the indicators.

The following section describes the progress to-date regarding this roadmap development.

4.2 Progress To-date

LUV and the University of Melbourne researchers have progressed the abovementioned phases 1, 2 and 3 to some extent. They have recently formed a steering committee to formulate the Victorian 3D digital cadastre roadmap. The committee members have been attending regular workshops.

The following draft vision statement has been developed by the steering committee which is currently under discussion and refinement:

By 2025, implement a digital cadastre that:

- *accurately delineates Victorian property boundaries in 3D*
- *defines the legal rights, restrictions and responsibilities of all parcels and their associated physical objects*
- *delivery of cadastral data is to an industry accepted single modelling standard*
- *facilitates 3D visualisation, validation, storing, updating, interoperability and interrogation of cadastral data*
- *enables key stakeholders to make timely and efficient decisions*
- *supports integration with existing cadastral systems and databases.*

The committee members have also agreed that the roadmap, aiming to support a smooth transition from the current cadastre to a fully operational 3D digital cadastre, should recommend several research projects around the following areas:

- A cost-benefit analysis to justify the government implementing a 3D digital cadastre. The rationale behind this project should consider the economic, social and technical aspects.
- Monitoring the technological trend within the areas of 3D data capture, validation, visualisation, database management, etc. The technologies selected for the 3D digital cadastre should be able to address the scalability, extendibility, and interoperability requirements in the future.

- Determination of the 3D data modelling and format (among LandXML, IFC, etc).
- Exploration of the readiness of the Victorian jurisdiction in terms of adopting a 3D digital cadastre. For example, the legal branch of LUV would need to investigate the legalities of transitioning from paper-based plans to digital data for legal purposes, e.g., contract of sale, legal disputes, etc.
- Alignment of the roadmap with the higher-level strategies including the LUV strategic plan, Department of Environment, Land, Water and Planning (DELWP) Corporate Plan and the ICSM cadastre 2034 strategy.
- Identification of the 3D digital cadastre stakeholders and the institutional changes that they need to make. An example would be the potential examination process change in LUV for examining the digital building subdivisions.
- Realisation of the 3D digital cadastre applications such as underground, aboveground, mining, agriculture, and built environment applications.
- Piloting a defined and developed area within Victoria that can be used to better understand the requirements of a 3D digital cadastre, e.g., Fishermans Bend in Port Melbourne.

5. CONCLUSION AND FUTURE PLAN ACTIONS

Currently, LUV is investigating a 3D digital cadastre in Victoria to support strata plans in ePlan. This requires significant investigation in various aspects of a 3D digital cadastre. In terms of legal aspect, there is an analogue 3D digital cadastre in Victoria and ownership rights are defined in 3D in paper or PDF based plans using floor plans and cross-sections.

In the institutional aspects, significant changes are required in the government processes, stakeholders and surveying industry. This is clearly seen in implementing the 2D ePlan in Victoria (Olfat *et al*., 2018). However, on the technical side, the technology supports this change.

At the moment, the main problem is the lack of a roadmap to guide Victoria to research and develop a fully operational 3D digital cadastre to achieve its goals. This roadmap is being currently designed and developed through a collaboration between LUV and the University of Melbourne.

In this paper, a method was proposed to develop the 3D digital cadastre roadmap in four main phases including:

- Phase 1: planning and preparation
- Phase 2: visioning
- Phase 3: roadmap development
- Phase 4: roadmap implementation, monitoring and revision

In Victoria, several workshops have been conducted by a steering committee formed by LUV and the University of Melbourne. The committee has progressed the above-mentioned first three phases to some extent. A vision statement and the required research projects have been recommended. The committee will continue running workshops to develop the first draft of the Victorian 3D digital cadastre roadmap. The roadmap will then be discussed with a selected group of the 3D digital cadastre stakeholders in Victoria including LUV, surveyors, councils, developers, building managers, and the public. The stakeholders' feedback will be incorporated into the roadmap, and the first version of the roadmap will be shared with the ICSM to ensure that it is aligned with the cadastre 2034 strategy. Potentially, the Victorian 3D digital cadastre roadmap can be adopted by other Australian jurisdictions.

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BIOGRAPHICAL NOTES

Davood Shojaei leads the 3D digital cadastre research at Land Use Victoria, within the Department of Environment, Land, Water and Planning in Melbourne. He has extensive experience over the last 15 years in designing and implementing a variety of research and industry projects, ranging from GIS, cadastre and BIM, to 3D visualisation. Davood completed his PhD on 3D cadastre visualisation at the University of Melbourne in 2014. He is currently working on the ePlan project to develop and implement digital cadastre services in Victoria.

Hamed Olfat joined the Victorian ePlan team 6 years ago once he finished his PhD in Geomatics Engineering at the University of Melbourne. He is currently the Coordinator of ePlan project and Chairman of the ICSM ePlan Working Group Technical Committee. Hamed also has the experience of working in the academia and private sector as a geospatial researcher and consultant for 8 years.

Abbas Rajabifard is professor at the University of Melbourne and head of the Department of Infrastructure Engineering and Director of both the Centre for SDIs and Land Administration and the recently established Centre for Disaster Management and Public Safety, at the University of Melbourne. He is immediate Past-President of Global SDI (GSDI) Association and is an Executive Board member of this Association. Abbas is the Chair of the UN-GGIM Academic Network. He has also consulted widely on land and spatial data policy and management and SDI.

Mohsen Kalantari is a lecturer in Geomatics at the Department of Infrastructure Engineering and Associate Director at the CSDILA. Dr. Kalantari teaches Land Administration Systems (LAS) and his area of research involves the use of technologies in LAS and SDI. He has also worked as a technical manager at the Department of Sustainability and Environment (DSE), Victoria, Australia.

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