Land and Property Information in 3D

Abbas RAJABIFARD, Mohsen KALANTARI and Ian WILLIAMSON, AUSTRALIA

Key words:

3D Cadastre; Legislation; Land Administration, Land Development; Property

SUMMARY

People increasingly live in high density urban, often high rise and multi functional buildings. These increasingly urbanized populations will predominantly live in multi-level, multi-purpose, highly engineered, high-rise developments. Cities require significant infrastructure above and below the ground. Rapidly expanding vertical cities and their populations will experience a range of new environmental, social and economic challenges.

The lack of an efficient and effective three dimensional solution limits the ability of the public to visualize and communicate 3D developments, the ability of architects, engineers and developers to capitalize on the full potential of 3D title models; the ability of governments and developers to visualize multi-level developments resulting in increased costs and delays; and the ability of land registries to administer a title registration system that can accommodate these increasingly complex multi-level developments.

This paper aims to introduce an approach which helps address the problem of modelling and managing complex 3D property rights, restrictions and responsibilities (RRR). The outcomes of this research incorporate the third dimension of height into the land subdivision and development process to build an infrastructure for managing and modelling spatial extension of these complex property RRRs. This research moves the multiple two dimensional drawings that now identify buildings and infrastructure objects and their separate parcels into authentic visual 3D representation of the building and objects that meet the exacting legal standards of ground surveys.

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1. INTRODUCTION

People increasingly live in high density urban, often high rise and multi functional buildings. Cities require significant infrastructure above and below the ground in unique titles and arrangements. For instance, disputes arising from high density living in buildings with owners corporations increase as the public bring their expectations, while living in detached houses, into the village atmosphere of projects. Disputes among owners, owners and their corporations and owners and third parties, will increase in numbers and complexity. So will the efforts of institutions such as courts, administrative tribunals and informal dispute settlement centres, and bureaucracies to service them.

2D survey plans (even with stratum boundaries specified) are no longer able to represent the reality of these inter-related titles and land uses with their complex rights, restrictions and responsibilities (Figure 1). In addition, the 3D software applications in engineering, architecture and geographic information systems do not have the integrity demanded in land administration and property management where legal accuracy is axiomatic.

Figure 1: High rise building and its 2D representation in a land subdivision plan

Multiple page 2D plans cannot be easily understood or visualized outside the domain of the highly specialized professional cadastral surveyors. At the same time, 3D engineering architecture drawings do not deliver legal authority for rights, restrictions and responsibilities in land and property registration.

The lack of an efficient and effective three dimensional solution limits the ability of the public to visualize and communicate 3D developments, the ability of architects, engineers and developers to capitalize on the full potential of 3D title models; the ability of governments and developers to visualize multi-level developments resulting in increased costs and delays; and the ability of land registries to administer a title registration system that can accommodate these increasingly complex multi-level developments.

The importance and urgency of finding a solution for Australian cities has brought together research partners from the key government agencies, the national coordination bodies for these issues, experienced private sector professionals and companies in the development of multi-level developments, and a research team at Centre for SDIs and Land Administration, the University of Melbourne to provide a solution as a remedy to the dominance of the 2D approaches and the lack of proper technology and systems within the spatial industry globally.

This paper aims to introduce a research project on Land and Property Information in 3D. The paper, in Sections 2 and 3, discussed the drivers for having the digital land and property information in 3D and benefits of it. Section 4 identifies the knowledge gap that the project will address. Section 5 then articulates aims and objectives of the project. Building on the previous section, Section 6 explains the project approach. Finally, in Section 7, progress to date is demonstrated.

2. DRIVERS FOR LAND AND PROPERTY INFORMATION IN 3D

The world's population is being urbanized: the majority of people now live in towns and cities (UN-FPA 2008). Australia is also experiencing this urban migration. The ABS projects Australia's population to almost double over the next 47 years increasing from 22 million to up to potentially 42.5 million by 2056 (ABS 2008).

The majority of these people will live in cities. These increasingly urbanized populations will predominantly live in multi-level, multi-purpose, highly engineered, high-rise developments. Rapidly expanding vertical cities and their populations will experience a range of new environmental, social and economic challenges.

It is essential the infrastructure is in place to model and manage these new 3D environments (UN-FPA 2008). This infrastructure should include verified, authorised, repeatable, engineered information about 3D environments, not just the surveyed external boundaries of structures and parcel boundaries that appear in 2 dimensional drawings.

The problem of creating efficient and accurate spatial representation of people's rights, restrictions and responsibilities in buildings and infrastructure above and below ground is shared by all cities of the world, irrespective of the level of development (Figure 2).

Figure 2: Busy high-rise megacities like Hong Kong, China (Williamson et al. 2010)

The third dimension of height in land information systems facilitates subdivision of space into strata legal property objects capable of being owned by different entities and used for unrelated purposes while facilitating management of the entirety. This creates separate legal property objects above or under the original property parcel or unit. The most typical objects located above the surface are apartments or buildings registered as separate property (Figure 3).

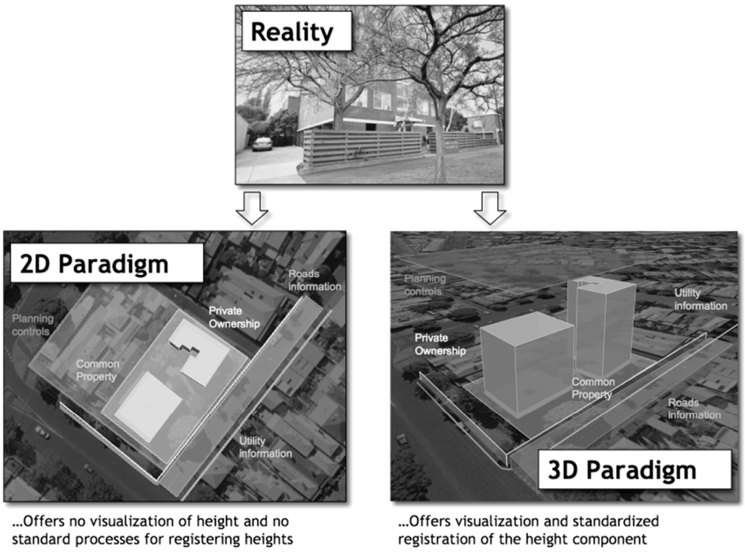

Figure 3: 3D objects representation

Increasingly, construction below or above the surface, such as tunnels and platforms used as foundations for buildings and so on, are also treated as 3D objects in a land subdivision process (Stoter 2004) . In some jurisdictions, networks such as telecommunication lines, water pipes and gas supply grids, and communication systems may also be registered, either within the land registry (as has been proposed in The Netherlands) or in a separate register (as for high-voltage power lines in Norway). 3D land and property information systems (3D cadastres) can also include interests related to trees, vegetation, minerals, hydrocarbons, as well as water (Bennett et al. 2005; Rajabifard et al. 2006 Kalantari et al. 2008).

Factors that highlight the need for land property information in 3D include an increase in property values, escalating numbers of overlapping transport routes, proliferation of utility infrastructure including cables and pipelines, management of complex natural environments alongside built infrastructure, and emergence of useful 3D technologies for design, planning and management.

Also, in current land information system data models, the third dimension is usually inadequately modeled as a 3D tag linked to the parcel record (Stoter and Oosterom 2003). The increasing complexity of modern cities demands that modern land administration systems include heights and capacity to visualize inter-relationships between structures and uses for sustainable management (Wallace and Williamson 2004).

The land administration sector in Australia recognizes the importance of having land information in 3D, especially in cadastres. Australia's Intergovernmental Committee on Surveying and Mapping (ICSM) which includes all land administration authorities in Australia , in its 'Strategic Pathways and Milestones 2008-2010' (ICSM 2008), identified the 3D cadastre as an emerging trend and supported research into 3D cadastre development. The Committee instigated an ICSM Strata Working Group to develop a framework for a 3D spatial land information system. Accordingly two land administration authorities and a national coordination body have committed significant resources to this project. In addition, three key private organizations active in land subdivision and construction in multi-level developments have given their support in this project with a significant resource commitment.

The involvement of industry partners in the research project will assist the implementation of the land and property information system in 3D by focusing on the development of partnerships as a means of solving issues in relation to the increasing number of interests in land. This will build the research capacity in Australia to further investigate different technical, policy and institutional aspects of 3D land and property in 3Ds.

The project partners include Land and Property Information NSW, Department of Sustainability and Environment (DSE), Land Victoria, Intergovernmental Committee on Surveying and Mapping Australia (ICSM), VEKTA, Alexander Symonds, PSMA, Australia, Strata Communities Victoria (OCV), Fender Katsalidis Architects (FKA).

3. BENEFITS

The ability to maintain 3D information relating to property interests, and make it available through the land administration systems will provide important benefits at governments levels. Its greater benefits lie at the public level where it will assist management of the economy of 3D land development, security of tenure and community engagement.

Building approvals data show a trend of strong growth in approvals for residential dwellings in inner city areas of many Australian cities (ABS 2009). Implementation of a 3D land and property information system potentially provides significant long term benefits and savings for the community in the land development processes as more than 50 percent of land development proposals involve height allocations.

A clear understanding of 3D developments through computer visualization will help reduce misunderstandings and disputes between developers, owners and managers, and the public. At the same time this will improve the ability of authorities, such as local government and utility companies, to effectively plan large multi-unit developments such as shopping centers, bridges and tunnels.

Access to comprehensive and integrated land and property information in 3D will modernize processes of land and property development in Australian cities and prevent confusion, administrative friction and disputes during decision making.

An aggregated database of different disciplinary datasets, such as land valuation, land use, utility management, property tenure, lease and occupancy in a 3D environment will provide municipalities and utility companies with the seamless information and tools to facilitate comprehensive and efficient engagement with the community.

Currently, in Australia, principles for recording overlapping interests in land are fragmented and not available in a cohesive and integrated way. Historically 2D systems managed interests in land and property effectively. These flat systems cannot manage the increasing number of 3D property rights, restrictions and responsibilities in Australia.

The fast growing populations and pressure to integrate facilities on, above and under the surface of cities and natural environments demand the introduction of a holistic approach to managing the third dimension in Australia. The availability of 3D spatial land information systems will enable governments to effectively respond to the fast growth of Australia's cities.

4. KNOWLEDGE GAP

The problem is the lack of a three dimensional solution (3D) to replace the current inadequate two dimensional (2D) representations and registration systems for complex rights, restrictions and responsibilities in modern cities (Figure 4) and sensitive natural environments. This is a problem in both the developed and developing world with no suitable solution in any jurisdiction globally even though it is an area of intense interest.

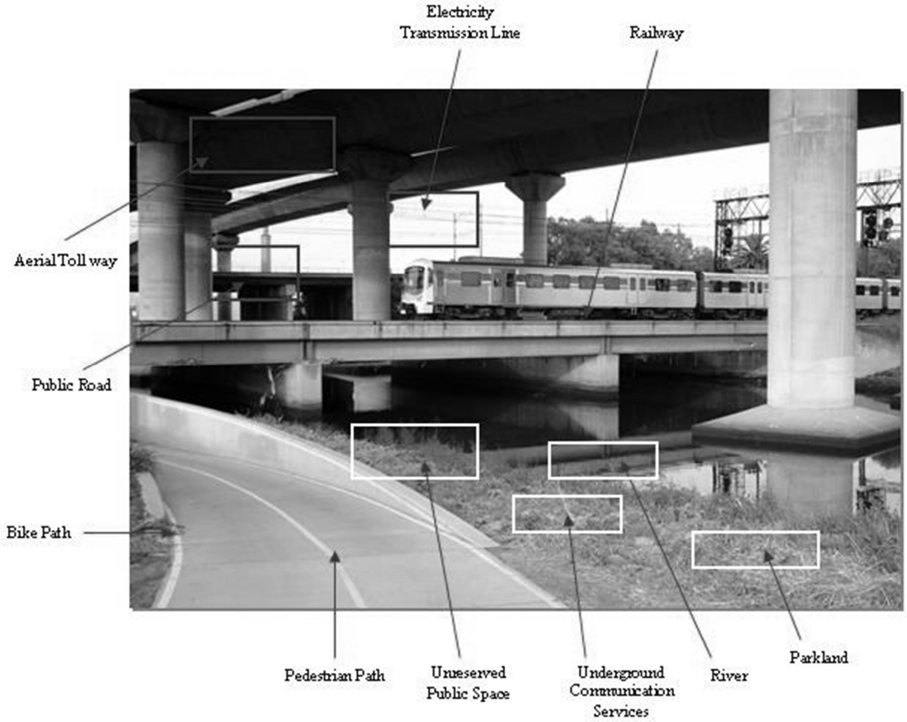

Figure 4: Complex rights, restriction and responsibilities in land (Williamson et al. 2010)

The existing property information systems, based on 2D flat maps, are unsuitable representations of the spatial geometric realities that have evolved in recent decades in rapidly growing, land scarce, cities. It is necessary to amend the legislation and define a new spatial and 3D land and property information model (Benhamu and Doytsher 2003) to facilitate the continued establishment of engineering projects below and above the surface, and particularly to enable the registration of properties that are not on the surface.

2D maps and plan drawings restrict the potential of multi-level developments, increase the cost of developments and limit inclusion of the new multi-unit developments in traditional land information and land registry systems. Land administration systems and property management need a new 3D paradigm to represent the inter-relationships of these floating and sub-surface freeholds and to express the complex rights, restrictions and responsibilities of modern close proximity living. This paradigm is likely to involve a mixture of new spatial technologies, laws and regulations and administrative systems, and is usually referred to as a 3D cadastre as distinct from the traditional 2D cadastre described above.

5. AIMS AND OBJECTIVES

This project aims to develop an innovative infrastructure which helps address the problem of modeling and managing complex 3-dimensional (3D) property rights, restrictions and responsibilities (RRR) in multi-level developments in our rapidly growing cities. This project will incorporate the third dimension of height into the property and land information systems (Cadastre) to build an infrastructure for managing and modeling spatial extension of these complex property RRRs. This research moves the multiple two dimensional drawings that now identify buildings and infrastructure objects and their separate parcels into authentic visual 3D images of the building and objects that meet the exacting legal standards of ground surveys. Property information systems based on 2D maps have served land administration and property management well for hundreds of years (Figure 5) based on the cadastral concept of an inventory of property parcels in two dimensions (FIG 1995).

However, most of the developed world (including Australia) and many developing countries now give ownership titles in buildings in three dimensions (3D) using the same 2D maps developed for traditional broad acre development on vacant land (Williamson 2002). It is the technical, legal and administrative problems surrounding the property rights, restrictions and responsibilities in the third dimension that are the focus of this project.

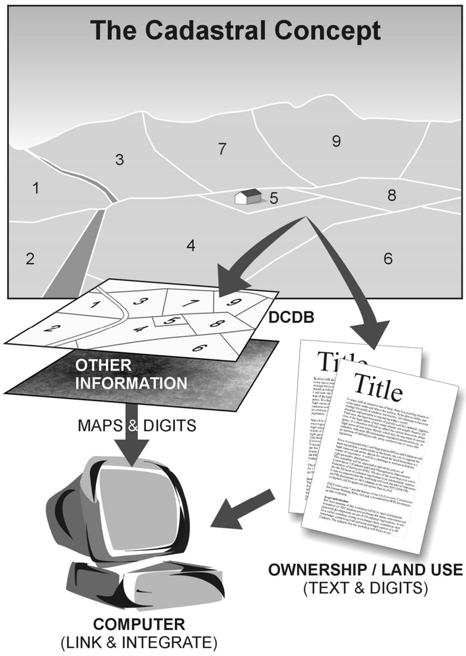

Figure 5: Traditional 2D cadastre - Conceptual Diagram (FIG 1995)

This project aims to deliver:

- An improved understanding of the problems and issues associated with incorporating 3D property information into land administration systems;
- A specification of the technical, policy, legal and institutional aspects of a 3D property information and representation system;
- A 3D data model and database management system;
- A 3D representation and registration model; and
- A prototype 3D property information and building representation system.
- A method to integrate 3D land and property information into 2D legacy systems
- A specification on policy, legal, institutional aspects of complicated management of

multi-level developments

6. APPROACH

Analysis draws on policy, legal and institutional issues associated with adding a legally authoritative third dimension to administration of land, and also technical issues in Information and Communications Technology (ICT) and spatial land information database management. Alternatives will be developed so that 3D information and interests are incorporated into the government land information repository to address the inadequate presentation and registration of 3D objects in cadastres. These include the development of institutional and legal requirements and then development of technical solutions to verify implementation of the requirements. Pilot projects, including using complex 3D developments in two of the partner jurisdictions, will test the research outcomes. The research process is described in Figure 6.

Pilot projects will test the major research objectives of the project, which will develop an integrated 3D registration and presentation model, including legal and institutional requirements in the technical contexts. Each of these three legal, institutional and technical areas will require significant input from different project partners, building on the unique strengths of each partner. The pilot projects will enable the specific needs of project partners to be taken into account, and will demonstrate proof of concept of the research application utilizing existing spatial data sets and tools used by the partners.

The pilot projects in particular will focus on more complex rights, restrictions and responsibilities, such as multi level developments in order to create an approach that can be utilized for a wide variety of interests, including those which would not be considered as legislating interests in land. Research undertaken in relation to organizing rights, restrictions and responsibilities in land has already demonstrated the value of the concept of the legal property object (Kalantari et al 2008). The pilot will utilize this concept, along with more traditional 3D interests in land e.g. building ownership or owners corporations.

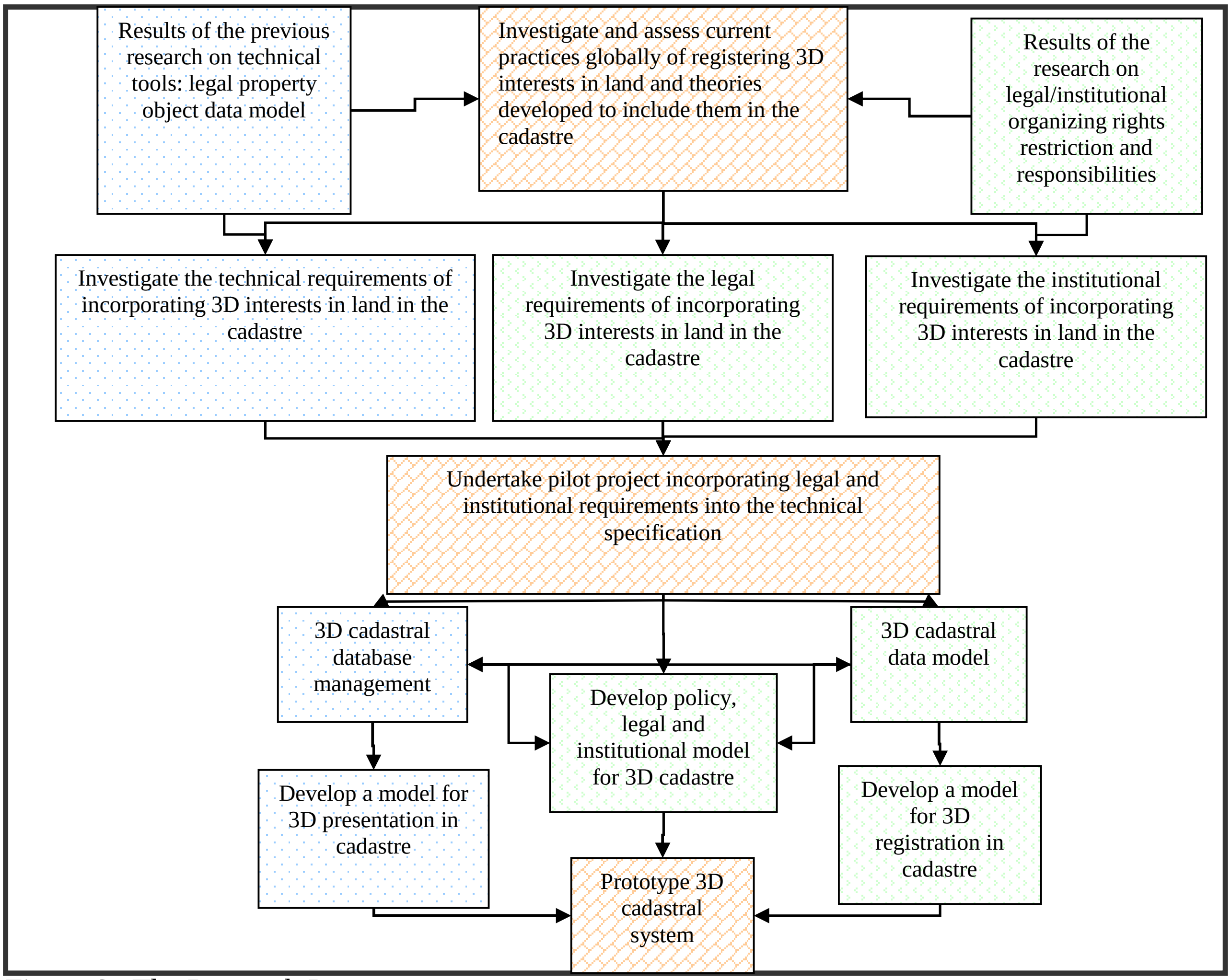

Figure 6: The Research Process

7. PROGRESS TO DATE AND FUTURE DIRECTION

7.1 Data model for 3D Cadastre

Current cadastral data models use a 2D land-parcel definition and extend it to cover 3D requirements. This approach cannot adequately manage and represent the spatial extent of 3D land rights, restrictions and responsibilities (3D RRRs) and other land administration functions land use, land value and land development.

The project has developed a 3D Cadastral Data Model (3DCDM) to configure 3D cadastral frameworks, manage and represent 3D RRRs, and facilitates 3D cadastre implementation. Three underlying principles have been proposed to develop the 3D Cadastral Data Model (3DCDM). According to (Aien et. al. 2011a and 2011c), these principles are:

Principle 1: The 2D cadastre data model is a sub-set of the 3D cadastral data model,

Principle 2: The 3D cadastral data model should not only accommodate 3D RRRs and their association with physical objects: the data model should also represent the spatial extent of 3D RRRs, and;

Principle 3: The 3D cadastre data model should cater for a broad range of land administration functions including land tenure, land value, land use, and land development with sufficient detail.

7.2 Cadastral requirements for visualizing land and property information in 3D

Current registration of 3D developments in most of countries and jurisdictions is based on 2D paper diagrams. These 2D representation methods employ different techniques such as cross-sections or isometric views. While this has been a common practice for experts such as land registration officers and cadastral surveyors, non-experts such as the public, lawyers and real estate agents often find these methods difficult to understand particularly in modern complex land developments. The requirements for 3D visualization of properties and interests have been developed. The requirements are classified into three categories (Aien et. al. 2011b):

The first category includes cadastral features such as processing a large volume of data, visualization of functions and queries, measurements, underground visualization, cross-section view and non-spatial data visualization. The second category, visualization features, include technical diversity, interactivity and visual representation. The third category, general features, is not related directly to the visualization, but it should be considered in any software product such as integration and interoperability, complexity, platform independency, dissemination and cost.

7.3 Software platform for 3D data management

Currently, a large number of tools and platforms using various technologies have been developed to facilitate 3D spatial data visualization. Platforms such as Google Earth, K2VI and 3D city models (e.g. Berlin city model) focus on improving the visualization techniques to convey 3D information about the world. Despite their flexibility in manipulation of objects in the 3D environment and presentation of the scene to the user, these tools generally lack underlying capabilities to complete a comprehensive visualization for rights, restrictions and responsibilities in land.

A web-based prototype platform has been designed, developed that is used for 3D visualization of the cadastral data. The platform addresses the limitations of current tools and approaches to build a seamless and integrated web-based 3D platform that supports 3D visualization in a user-friendly environment (Amirebrahimi and Rajabifard 2012).

The project has developed a system for visualization of 3D rights, restrictions and responsibilities in a multi-level building. This prototype system is developed based on a threelayer framework including, data, processing and visualization layers. The system demonstrates different capabilities including interactive cross-sections of structures, 3D measurements, and 3D representation of interests above and underground structures and utilities.

7.4 Institutional and legal aspects

Within the context of this project, the question arises as to whether current land development processes, which are underpinned by two-dimensional systems, are efficiently supporting land administration pertaining to high rise multi-unit developments? Consequently, with a growing worldwide trend towards utilising three-dimensional technologies in many aspects of urban management, can the land development process for high rise development benefit from moving to a 3D system? A crucial aspect in considering this issue is to examine the institutional structures around the current land development process to determine how, and where, 3D systems could be most critically adopted (Ho and Rajabifard 2012).

ACKNOWLEDGEMENT

The authors would like to acknowledge the assistance of our members of the Centre for SDIs and Land Administration and the Department of Infrastructure Engineering at the University of Melbourne in the production of this paper. We would also like to thank our ARC Linkage Grant research partners for their support and provision of qualitative data. It should be noted that the views expressed in this paper are those of the authors and may not represent those of the research partner organizations.

REFERENCES

ABS (2008). “3222.0 Population Projections, Australia, 2006 to 2101”. Retrieved October 2009, from http://www.abs.gov.au/Ausstats/abs@.nsf/mf/3220.0.

ABS (2009). 8731.0 - Building Approvals, Australia, Sep 2009, Retrieved October 2009, from http://www.abs.gov.au/AUSSTATS/abs@.nsf/mf/8731.0

Aien, A., Kalantari, M., Rajabifard, A., Williamson, I., and Bennett, R. (2011a). Principles of 3D Cadastral Data Modelling. Proceedings of 2nd International Workshop on 3D Cadastres 16 -18 November, organized by FIG, EuroSDR and TU Delft.

Aien, A., Rajabifard, A., Kalantari, M., Williamson, I., and Shojaei, D. (2011b). 3D Cadastre in Victoria. GIM International Magazine, Issue 8, Volume 25, August 2011

Aien, A., Rajabifard, A., Kalantari, M., and Williamson, I. (2011c). Aspects of 3D Cadastre- A Case Study in Victoria. Proceedings of FIG Working Week 2011, 18-22 may Marrakech , Morocco

Amirebrahimi, S., and Rajabifard, A. (2012). An Integrated Web-based 3D Modeling and Visualization Platform to Support Sustainable Cities. Proceeding of the XXII International Society for Photogrammetry & Remote Sensing Congress, Melbourne 25 Aug- 1 Sep.

Benhamu, M. and Doytsher, Y. (2003). "Toward a spatial 3D cadastre in Israel." Computers, Environment and Urban Systems 27(4): 359-374.

Bennett, R., Wallace, J. and Williamson, I. (2006). "Managing rights, restrictions and responsibilities affecting land". Combined 5th Trans Tasman Survey Conference &

2nd Queensland Spatial Industry Conference 2006 ,Land and Sea Spatially Connected, In A Tropical Hub, Cairns, 18-23 September 2006.
Bennett, R., Williamson, I. and Wallace, J. (2005). "Achieving sustainable land management through better management of rights, restrictions and responsibilities ". Expert group meeting on incorporating sustainable development objectives into ICT enabled land administration systems, Melbourne, Australia, December 2005.
FIG. (1995). "FIG statement on cadastre." Retrieved July, 2005, from http://www.fig7.org.uk/publications/cadastre/statement_on_cadastre.html.
Ho, S. and Rajabifard, A. 2012. 3D Land and Property Information System: A Multi-level Infrastructure for Sustainable Urbanisation and a Spatially Enabled Society. In D. Coleman and A. Rajabifard (eds.), "Spatially Enabling Government, Industry and Citizens: Research and Development Perspectives". Publication forthcoming.
ICSM (2008). "Strategic Pathways and Milestones 2008-2010", Intergovermental Committee on Surveying and Mapping.
Kalantari, M., Rajabifard, A., Wallace, J. and Williamson, I. (2008). "Spatially referenced legal property objects." land Use policy.
Rajabifard, A., Binns, A., and Williamson, I.P. 2006, 'Virtual Australia- An enabling platform to improve opportunities in the spatial information industry', Journal of Spatial Science, Special Edition, Vol. 51, No. 1.
Stoter, J. and Oosterom, P. V. (2003). "Cadastral registration of real estate objects in three dimension." URISA 15(2): 47-56.
Stoter, J. E. (2004). 3D Cadastre. Geodesy. Delft, Technical University of Delft. 327.
UN-FPA. (2008). "State of World Population 2008." Retrieved 7 July 2009, from http://www.unfpa.org/swp/.
Wallace, J. and Williamson, I. (2004). "Developing Cadastres to Service Complex Property Markets". Joint FIG Commission 7 and COST Action G9 Workshop on Standardisation in the Cadastral Domain, Bamberg, Germany, December 9-10.
Williamson, I.P., Enemark, S., Wallace, J. and Rajabifard, A. 2010, Land Administration for Sustainable Development. ISBN 9781589480414, ESRI Press. USA, 517 pp.
Williamson, I. P. (2001). "Land Administration Infrastructure: The Other Side of The Coin Seminar on Securing Land for the Urban Poor ". United Nations Centre for Human Settlements (Habitat) /United Nations Economic and Social Commission for Asia and the Pacific, Fukuoka, Japan, October 2-4
Williamson, I. P. (2002). "The Cadastral "Tool Box" - A Framework for Reform". XXII FIG International Congress, Washington DC, U.S.A. , April 19-26

BIOGRAPHICAL NOTES

Abbas Rajabifard is a Professor and Head of Department of Infrastructure Engineering at the University of Melbourne. He is also Director of the Centre for SDIs and Land Administration (CSDILA). 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 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.

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 Infrastructure Engineering, University of Melbourne, Australia. His expertise is the cadastre, land administration, and spatial data infrastructures.

CONTACTS

Abbas Rajabifard
University of Melbourne
Parkville
Victoria
Australia 3010
+61 3 8344 0234
abbas.r@unimelb.edu.au
http://www.csdila.unimelb.edu.au/people/rteam/abbas.html

Mohsen Kalantari
University of Melbourne
Parkville
Victoria
Australia 3010
+61 3 8344 4789
saeidks@unimelb.edu.au
http://www.csdila.unimelb.edu.au/people/rteam/mohsen.html

Ian Williamson
University of Melbourne
Parkville
Victoria
Australia 3010
+61 3 8344 5597
ianpw@unimelb.edu.au
http://www.geom.unimelb.edu.au/people/ipw.html