3D Cadastres and Beyond

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SUMMARY

How does the cadastre deal with an urban environment that is increasingly populated and structurally complex? The development and implementation of 3D digital cadastres is now positioned as a necessary – and urgent – response: it is no longer just about land; it can be expected that in the future, the majority of lots created will be associated with vertical developments. It is essential that the recording, managing and communication of information about the legal extent of property rights, restrictions and responsibilities (RRRs) for vertical developments and stratified RRRs are accurate and unambiguous.

The realisation of 3D cadastres, and indeed, to realise cadastres that will be sustainable into the future, requires the consideration of how the needs of current users should be balanced against the potential needs of future users. In the data-rich environment of today's smart cities, 3D digital cadastral information offers the land administration industry new engagement opportunities.

Based on a range of professional experiences, this paper offers a perspective on 3D cadastre developments and a consideration of where the future might lie; in particular, an emphasis on the role of cadastres in the genesis of new connections between wider society, across state boundaries, and in supporting the delivery of other national visions, digital economy, foundation datasets and smart cities. The realisation of 3D cadastres, and indeed, to realise cadastres that will be sustainable into the future, requires the consideration of how the needs of current users should be balanced against the potential needs of future users. We need to accommodate the needs and opportunities of future cities and consider what must be done to ensure institutional sustainability.

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1. INTRODUCTION

Our world is an increasingly urban one and the environment that we inhabit is becoming more dense and complex as we contend with the pressures of urbanisation and respond to the needs of a growing urban population.

Today, the urban population makes up more than half of the world's population – in 1960, this proportion was only around 30 percent – and from as soon as 2017, the majority of the world's population will be concentrated in urban areas (World Health Organisation, 2014). Urbanisation has been suggested as the "single greatest change in this century", particularly in developing countries where the urban built-up area is projected to triple between 2000 and 2030 (Suzuki et al, 2010). Sustainable urbanisation is a multi-faceted challenge and one of the more prominent responses, whether rightly or wrongly, is the use of high-rise, high-density buildings as the dominant urban form.

The social, environmental and economic aspects of these buildings are supported by land administration systems, given their fundamental role in managing and administering information about tenure, value, use and development of land (FIG, 2005). However, these systems, and their core cadastral systems, are predicated on longstanding 2D-based practices of recording and representing land and property information that are proving to be limited in their ability to facilitate unambiguous and accurate recording and representation of complex ownership rights, restrictions and responsibilities (RRRs) defined in 3D, such as those inherent in high-rise buildings. The development and implementation of 3D digital cadastral systems is now positioned as a necessary and urgent response.

Based on a range of professional experiences, this paper offers a perspective on 3D cadastre developments and a consideration of where the future might lie, in particular, an emphasis on the role of cadastres in the genesis of new connections between wider society, across state boundaries, and in supporting the delivery of other national visions, digital economy, foundation datasets and smart cities.

2. COMPLEX CITIES AND THE NEED FOR INTEGRATED INFORMATION SYSTEMS

High-rise buildings, which have traditionally been used for commercial purposes, are now becoming a key urban response for housing in both developed and less developed countries, and is one that is endorsed both pedagogically and politically (e.g. Turkington et al, 2004; McConnell and Wiley, 2010; Yeh and Yuen, 2011; Rowley and Phibbs, 2012; Jackson, 2012). Globalisation has been a key motivator for this, where neo-liberal development models have contributed to a reliance on the commoditisation of real estate as a key pillar of new major economies, such as those seen in India and China (e.g. Deng et al, 2004; Ong, 2005; Mohammadzadeh, 2011). This drives a need for robust information about land and property rights, restrictions and responsibilities (RRRs).

Residential developments also arguably drive an accompanying need for investment in infrastructure and services such as laying utilities such as fibre optic networks, underground cities, large shopping complexes, subterranean rail systems. As spatial entities, these developments impact on the urban form, with corollary impacts on urban flow (e.g. energy, travel, etc) and function (e.g. land use) (Salat and Bourdic, 2012). We therefore need information about all aspects of the built form to facilitate better decision-making to support the functioning of our cities.

In addition, the growing adoption of urban consolidation strategies around the world produces a range of other challenges associated with the increase in size and complexity of high-rise apartment buildings. These include facilitating an inclusive, vibrant and liveable community environmental concerns, and complexity in economic, political and regulatory forces (e.g. (Randolph, 2006).

There is already evidence that an integrated and collaborative approach to planning and management of our urban environment can result in reduced environmental impact through conservation of resources and lower emissions such as those being witnessed in places such as Stockholm (Gaffney et al, 2007), Singapore (Tortajada, 2006) and Curitiba (IPPUC, 2009). The value proposition inherent in facilitating and maintaining well-functioning cities is evident in the role that cities play as economic engines engines (eg. Ciccone and Hall, 1996; Harris and Ioannides, 2000; Ali and Moon, 2007). In Australia, the major cities, comprising less than 0.2 percent of total land area, contribute almost 80 percent of the country's GDP (Kelly and Donegan, 2014).

Bringing together all the various and disparate sources of information about our built environment has become a sustainability imperative, and 3D cadastres can provide the accurate, authoritative and unambiguous foundation for understanding the urban form.

3. DEVELOPMENTS IN 3D CADASTRES

Significant progress has been made in advancing the concept of 3D cadastres and related technologies to facilitate its realisation. These advances have been gaining momentum: over the last few years, we have seen the endorsement of the Land Administration Domain Model (a data model that makes allowances for recording 3D RRRs) as an ISO standard, and the number of jurisdictions that are now developing prototype systems and undertaking pilot trials to test conceptual boundaries and appropriateness have become more significant. Some of the countries that come to mind include Russia, China, the Netherlands, Indonesia, Australia and Malaysia.

Research on 3D cadastral systems is currently being undertaken in almost 30 different countries, culminating in four international workshops, most of which has only taken place over the last four years. This is a significant achievement, reflecting the level of stewardship of the International Federation of Surveyors' (FIG) Commissions Three and Seven, but also a telling indicator that a solution is being urgently sought.

However, the question to consider here is: is the current pursuit of 3D cadastres ***too*** specialised? In trying to realise 3D digital cadastral systems, are we ignoring the broader development landscape, of which our profession is a constituent? There are a number of FIG declarations that have long emphasised the role of cadastral systems must play in supporting sustainable development (e.g. Bathurst Declaration, 1999, Marrakech Declaration, 2002), which suggests that value to the community is best derived from not only having accurate fundamental information about tenure, but from the ability to integrate this with the broader information environment.

With the maturation and accessibility of 3D technologies, there is little doubt that we are now moving to embrace a 3D digital environment for land administration business practices, including an object-oriented approach to managing information about land and property RRRs. What we are attempting to do is occurring alongside broader trends in the land development industry that is focused on producing and using 3D-enabled information for facilitating the development and management of the urban built environment – particularly successful is the diffusion of Building Information Models (BIM) throughout the international land development sector, and increasingly the facilities management sector as well. However, should we continue in parallel, and are we headed in the right direction?

3.1 The specialised nature of cadastres

The fundamental role of cadastral information in underpinning property markets in western countries has necessitated legislative mechanisms to govern the generation and recording of such information. The recording and representation of cadastral information is a specialist practice – traditionally defined and determined by the profession of surveying.

There is evidence that much of the research currently being undertaken remains closely related to evolving current practices. For example in Australia, efforts are focused on implementing ePlan, the current data model endorsed by land registries, for 3D purposes. It makes sense, to build on what we already know; as well, ensuring that the integrity of current cadastral systems is preserved as we move towards truly digital systems is a high priority.

As those who work closely with cadastral information, we are highly cognizant of the fundamental role that cadastral systems have. However, this is not necessarily recognised by the broader community. This is apparent in many land governance structures around the world, where cadastral systems are subsumed under broader planning and development frameworks. Again, using Australia as an example, cadastral information is considered to be part of development assessment processes (see Figure 1), with subdivision given prominence for its role in facilitating supply of land to the community (Productivity Commission, 2011).

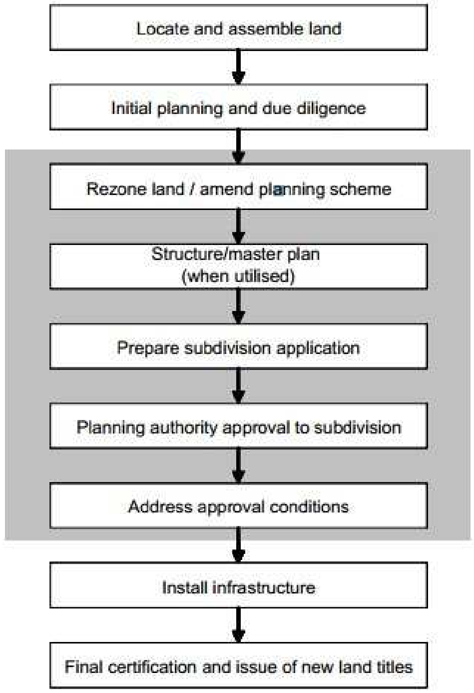

Figure 1. Simplified land supply process in Australia (grey shading indicates primary impact and influence of planning systems) (Productivity Commission, 2011: xxix)

3.2 The challenge for cadastres

Both practice and literature demonstrates that on both sides, the land administration industry has yet to effectively engage with other industries engaged with the built environment, such as architecture, engineering and construction, in setting the agenda for leveraging the broader 3D evolution. For example, national strategies developed to support the use of 3D information have been unlikely to accommodate cadastral information in the development of new processes to support adoption and implementation of 3D building information (e.g. BIM Industry Working Group, 2011) – as an industry, we are not visible.

This is likely due to the small presence of the surveying industry in the land development sector, estimated to comprise less than two percent of the total number of employed persons in the buildings network (Allen Consulting Group, 2010). However, we have also in recent years, adopted an increasingly technical approach to reforming cadastral systems, where although some attention has been paid to the legislative frameworks that we are regulated by, little effort has been made to better understand underlying institutional frameworks, and we have left unattended the broader social and cultural institutions that cadastral systems are positioned within which it needs to remain responsive to (Ho et al, 2015).

There is now recognition that the land administration industry is perhaps not as engaged as it should be with the demands and expectations of the community, and that national mapping agencies and cadastral organisations in particular, suffer from a "lack of institutional fit for the real world", (McGlade, cited in Haarsma, 2013: 17).

McGlade further notes that "This lack of institutional fit can be rather dangerous because it creates the nightmare scenario of a fragmentation of values… to the point where the institutes end up delivering completely inferior solutions to users, and not least to citizens" (Haarsma, 2013: 17). Traditional perceptions that place these agencies in the centre of the spatial sphere of influence have evolved, but not for the agencies themselves. The danger for us as an industry is that we may be running the risk of creating conflicting spheres of influence rather than complementary ones. This would be detrimental.

There is a need to be proactive, and research on 3D cadastres can be an important way to develop new connections. The challenge facing the land administration industry is one of engagement, and overcoming traditional 'silos' that prevent full participation in the broader 3D evolution. As a direction for progression, we should be exploring ways for our research to dovetail with these trends, rather than continue to exist only alongside it.

4. 3D CADASTRES AS PART OF A COLLABORATIVE APPROACH: DRIVERS AND OPPORTUNITIES

Although the 3D evolution may appear to be about 3D technological innovation, they are in fact focused on evolving current operational paradigms towards improved collaboration and data interoperability through a technological opportunity (Eastman et al, 2011). These themes should not be unfamiliar to the surveying, mapping and spatial sciences industry.

Looking back, an earlier FIG initiative, 'Cadastre 2014' (Kaufmann and Steudler, 1998), had already laid the foundation for much of the direction that 3D cadastres is now heading towards. 'Cadastre 2014' provided a simple yet effective framework for supporting the evolution of cadastral systems by establishing a set of universal principles that all countries could work towards, including the emphasis on information integration and shifts in collaboration dynamics across stakeholders that are recognised as the key benefits of leveraging 3D technologies.

Given the nature of the information held in land registries, there has always been recognition of the potential that cadastral systems have in supporting a broader range of environmental applications. This is evocative of previous discourses in the late 1970s around 'multipurpose cadastres' (e.g. McLaughlin, 1975), which arguably, is a notion that is still highly relevant today. More importantly in doing so, the connection of 3D cadastral information with the multiple information streams pertaining to the urban built environment preserves the relevancy and role of cadastral information as fundamental to all societies.

There are initiatives that suggest we are moving in this direction. In Europe, the cadastral parcel now has a more visible role in facilitating multiple aspects of land information management through an INSPIRE directive (INSPIRE, 2007). However, there are clear opportunities for exploring how best to position 3D cadastres as part of a much needed collaborative approach.

4.1 Building Information Modelling/Models and Precinct Information Models

One of the ways we to facilitate greater collaboration around the function of 3D cadastres is to explore opportunities for leveraging 3D technologies that are becoming mainstream, such as the use of Building Information Models (BIM), which are based on the open source Industry Foundation Class format.

BIM refers to two concepts simultaneously. There are numerous definitions but it is essentially recognised as a an information model, i.e. a **product,** where information about all the elements of a building are visualised as a 3D model, which is underpinned by a collaborative **process** for producing building information to serve as a unified repository of information about all components of the building that is accessible to stakeholders (e.g. NBIMS-US, 2014; Eastman et al, 2011; Smith et al, 2012).

BIM as both product and process innovation has delivered significant improvements in productivity across the land development industry, primarily in planning, coordinating and analysing building design across multiple stakeholders. The value in integrating building design information generated by multiple stakeholders in the development process lies in reducing the costs of design changes and improving project documentation. In modern developments where there can be up to 18 different stakeholders (Rahman, 2010), these costs have been estimated to be account for up to 30 percent of the total costs per project (Brown, 2008).

The use of these models have been growing exponentially – as much as 400 percent over the last five years in North America alone (McGraw-Hill, 2012). International trends are observed to be on a similar trajectory (Davis Langdon, 2012). BIM is no longer a disruptive phenomenon but represents a technological and an operational evolution that the land administration industry can ill afford to ignore.

Given the increasing turn towards mandatory use of BIM by national governments such as the United States, the United Kingdom, and Singapore, exploring the application of BIM for cadastral purposes makes sense: it facilitates a bridge between our industry and the broader construction and management industries and it places us in a equitable position to contribute to collaborative discussions regarding the sustainable development and management of the urban built environment.

Preliminary investigations at our research centre demonstrates the potential of using BIM for managing and representing 3D cadastral information, in particular, this would give the user full control over building components and functions (Shojaei, 2014). Figure 2 shows how the IFC data model was used to construct cadastral entities around ownership and easements. As an example, one legal property object is highlighted in green and associated legal information is represented in a window on screen.

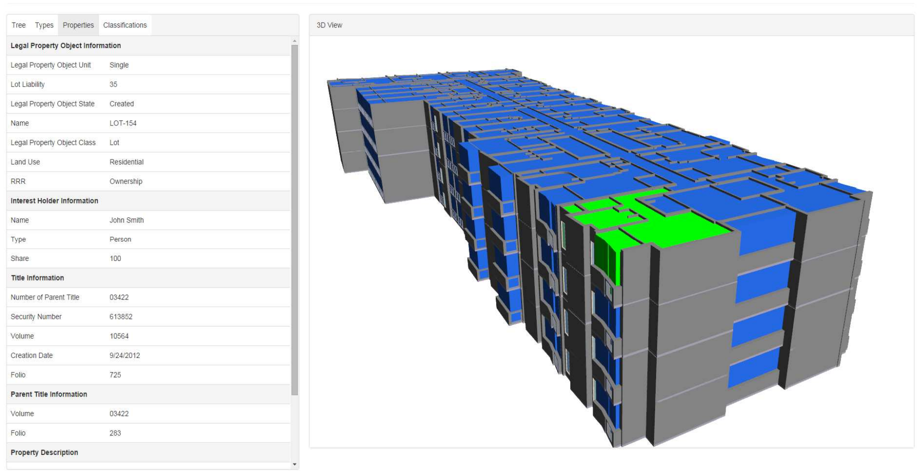

Figure 2. Managing legal/cadastral information in prototype cadastral BIM prototype model (Atazadeh et al, 2014)

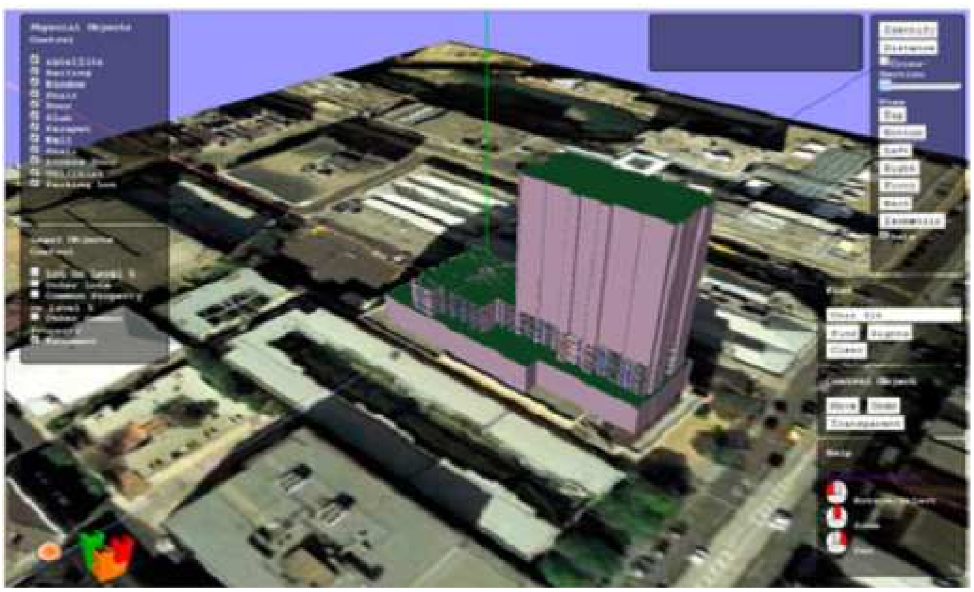

Figure 3. Visualising cadastral BIM prototype model online (Shojaei et al, 2014)

It was also possible to provide the community and relevant stakeholders with a way to visualise the cadastral BIM prototype model online, where users could see the relationship between cadastral information and the physical built environment. Figure 3 shows the online environment where the visualisation application provided users with a range of controls for identifying, querying and visualising different parts and functions of the building.

Associated with BIM is the concept of Precinct Information Modelling/Models (PIM), which extends the capabilities of BIM to the precinct level (Plume, 2013). This opens up new opportunities to evidence-based planning and precinct assessment. Currently, work on this area within Australia is occurring through a number of research groups and builds on research that uses IFC to store and represent cadastral boundary information.

4.2 Enabling technical frameworks

To bring multiple sources of 3D land and property information together inevitably requires an enabling technical architecture. This is a significant undertaking that must be able to bring respond to the multiple needs and requirements of stakeholders.

In Australia, Virtual Australia and New Zealand (VANZ) is being proposed with the key purpose of providing a federated framework of data banks that will hold multiple sources and formats of digital data and information about the built environment. This information while accessible, will remain under the control of the proprietary organisations. Ultimately, such a framework must still be based on common standards and in the case of VANZ, the ten foundation datasets recommended by ANZLIC – The Spatial Information Council, has been proposed as the requisite basis.

4.3 Enabling institutional frameworks

There are now instances of shifts at the policy level that recognise the value of 3D data and 3D technologies and 3D city models. There are some practical realisations of policies, e.g. the 3D pilot in The Netherlands led by four national organisations, and the development of a 3D virtual city model in Singapore, led by the Singapore Land Authority. For other countries like Australia and New Zealand, policies like the ‘Cadastre 2034’ strategy demonstrate clear recognition of the value of 3D land and property information although these are still in the early stages of being implemented. Increasingly, governments are also recognising that 3D land and property information can play a key role to play supporting e-government objectives (e.g. Tan and Hussin, 2012).

However, it is not only the role of government, but also the role of professional associations if there is to be a truly integrated approach to using 3D land and property information. Associations like buildingSmart are becoming prominent for their role in supporting professional training and development in the area of BIM. Academia must also feature as it is through the development of appropriate and forward-looking curricula that we can ensure that the information needs of our cities continue to be met.

4.4 The digital economy and smart city philosophy

Momentum in the digital economy is stimulating the production of digital information about the natural, built, social and legal aspects of the environment. The amount of data collected up till 2003 is now equivalent to the volume of data produced every two days (Wakefield, 2013). Multi-dimensional data and information are becoming increasingly available, such as 3D land and property ownership information and land use census data, which have the potential to underpin better planning for healthy, liveable and productive cities. Governments around the world are recognising the need to harness this wealth of information to facilitate design, development and management for sustainable development (NSTC, 2008).

This has led to the emergence of smart cities, whose underlying philosophy is to utilise ICT to develop intellectual capital and participatory practices in the governance of a city's resources (Hollands, 2008; Caragliu et al, 2011). Supporting the development of smart future cities will be a key strategy for urban sustainability, and the ability to plan for this will be incumbent on governments' ability to leverage the masses of data and information now available about many aspects of the built environment.

In particular, as the land administration industry has come to realise, there is a pressing need to better understand the multi-spatial properties of our cities – yet most analyses of cities continue to be undertaken using aggregate boundaries and in 2D space. Planning and decision-making for these multi-spatial challenges requires sophisticated tools incorporating comprehensive information in multiple dimensions.

5. DISCUSSION

The increasing technological orientation of cadastres should not detract from the fundamental role that cadastres have in society and the implications this has in supporting the genesis of new connections between wider society and across traditional jurisdictional boundaries. Solidifying this role will no doubt ensure that cadastres contribute to facilitating the delivery of other national visions, digital economies, fundamental datasets and realising smart, sustainable and resilient cities of the future.

It is imperative that cadastral systems can be linked with broader environmental information to support urban management. The ability to do so is of growing importance especially in our current digital milieu, where an unprecedented volume of data being produced in cities. In this environment, digital interoperability, particularly spatial digital interoperability, is fundamental and is being recognised as a key challenge and policy imperative by governments around the world (an example being the United Kingdom's current public consultation on spatial digital standards).

The realisation of 3D cadastres, and indeed, to realise cadastres that will be sustainable into the future, requires the consideration of how the needs of current users should be balanced against the potential needs of future users. We need to accommodate the needs and opportunities of future cities and consider what must be done to ensure institutional sustainability. If the land administration industry is able to engage more broadly and create an impact on strategic directions, 3D cadastres have the potential to deliver much more.

For this to occur, there is a need for the land administration industry to adopt a proactive approach to exploring solutions that extends beyond our traditional practicing paradigm to uncover the new connections that can be formed.

Figure 4. 3D cadastres as a way to build new connections

In the data-rich environment of today's smart cities, 3D digital cadastral information offers the land administration industry new engagement opportunities. Figure 4 proposes a potential situation where the presence of enabling technical and institutional frameworks can foster new connections (red dotted lines) between existing fragmented practices or data to support the development of smart cities that better engage our communities in a collaborate and community focused approach to ensuring sustainability.

There are many opportunities that presenting as potential areas of research. Some of these lie at the nexus of traditional silos such as those between land development and land management; integrating statutory data (e.g. property values) and socially-derived information (e.g. social media volunteered geographic information); bringing together data from multiple environmentally-oriented industries. Additionally, there are those opportunities driven by future needs, demands and expectations such as disaster management and public safety, planning and decision-making to secure liveability and productivity of cities, and urban resilience. The commonality across these various themes is that they are require a spatially accurate map base and 3D cadastres as foundations.

6. CONCLUSION AND FUTURE DIRECTIONS

The cadastre now needs to deal with an urban environment that is increasingly populated and structurally complex. The development and implementation of 3D digital cadastres is now positioned as a necessary and urgent. However, the realisation of 3D cadastres that will be sustainable into the future requires the consideration of how the needs of current users should be balanced against the potential needs of future users.

The paper highlighted a range of drivers and opportunities that can be leveraged to better connect 3D cadastres with the broader information environment. In terms of the future, the paper emphasised the role of cadastres in the genesis of new connections between wider society, across state boundaries, and in supporting the delivery of other national visions, digital economy, foundation datasets and smart cities. It illustrated a range of opportunities that can be explored for future research as these are all predicated on having 3D cadastres as a fundamental dataset. It is incumbent upon us to realise the opportunities that can be offered to the broader community by extending beyond our traditional boundaries to play a role in delivering a more sustainable urban future.

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