

AN OVERVIEW OF 3D CADASTRE FROM A PHYSICAL LAND PARCEL AND A LEGAL PROPERTY OBJECT PERSPECTIVE

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Key words: 3D Cadastre, property object, land parcel

SUMMARY

The physical land parcel based model of representing, storing and manipulating cadastral data, which includes two-dimensional geometry as well as the rights, restrictions and responsibilities attached to it, has largely been very successful in dealing with the present needs of land administration. The emergence of newer objects and interests on land, like, 3D titles, non parcel-based interests, interests extending beyond the physical boundary of a parcel and use of digital cadastral databases etc. have increased discussions on the need for a legal property object. From a 3D cadastral perspective, it has become necessary to find the right balance between the geometrical representation of the surface 2D parcel and the 3D object which may have different extents and interests as in the case for underground infrastructure. This makes it essential to approach 3D cadastre from both the land parcel as well as the legal property object perspective. This paper explores the various aspects and issues related to the technical, legal and administrative framework for the development and implementation of a 3D cadastre with particular emphasis on Queensland, Australia.

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1. INTRODUCTION

Throughout a large part of the history of human settlement, land has been one of the foremost sources of wealth, power and sustenance. In a monarchy or a feudalistic society, the primary ruling classes was to ensure that the fiscal privileges were accounted for by the tenant or owner of the land. So, land administration's primary function was to record ownership interests and serve as a fiscal tool for managing the taxation system (Larsson 1991).

Land administration systems have historically existed to gather revenue, protect people's rights to land, regulate the land market and control land use (Kalantari 2008). According to (Dale and McLaughlin 1999), land administration consists of three functions: juridical (for land tenure), regulatory (for land use), fiscal (for land value), with land information management integral to the three functions.

Modern day land administration has shifted the primary focus from a fiscal administration to a more comprehensive land management approach by integrating the contemporary concepts of the role of a land administration, while reflecting and adapting to the changing market demands or pull factors. The way land is used is driven by the interplay of social, economic, and environmental factors (Williamson et al 2005 as referred in Kalantari 2008). In the present context, the increasing complexity of modern cities suggests that modern land administration systems need an improved capacity to manage the third dimension of height (Zlatanova and Stoter 2006).

As land units were the primary focus of a land administration, cadastral systems and data models naturally developed around the land parcel for its administration and land information. However, as shown by (Kalantari et al 2008), land parcels are not sufficiently flexible to accommodate or support the growing number of complex commodities (e.g. water, biota, mining rights, 3D, and carbon credits) and other interests (e.g. environmental, heritage, use restrictions) in land.

A cadastre which uses a legal parcel object as a basis for data modelling for organizing, storing, managing of cadastral data as well as other complex commodities and interests has shown to be a flexible approach in organizing land information. However, changing the role of land administration in a society is not simple. This shift involves many issues relating to the historical, cultural, social, technical and economic situation of the society (Ting and Williamson 2000).

In this paper, the aspects of a physical land parcel and a legal parcel object are explored, and a comparison of the two in the context of a 3D cadastre is analysed based on various identified elements and functions of a land administration.

This paper is structured into five main sections: Introduction, Physical land parcel, Legal parcel object, Comparison of 3D cadastral object models and Discussions and further research. Following a brief introduction to the paper, section 2, Physical land parcel, deals with the existing land administration system of cadastre which is based on the parcel. Section 3 discusses the Legal parcel object as an alternative concept of land administration. Section 4 combines the two objects, and compares their relative merits or demerits to critically analyse them based on various aspects of a land administration. Section 5 concludes the paper with a Discussion summarizing the paper, with a sub-section on Further Research which proposes work that needs to be extended and studied in depth.

2. PHYSICAL LAND PARCEL

Cadastral systems are at present based on the physical land parcel. From the very beginning, it has been very successful in satisfying the needs of a cadastre. The parcel, which is an enclosed block of land, is the uniquely identifiable building block of the registration process, satisfying the capabilities of both the map makers as well as the record keepers. Further functionalities and complexities were constantly added to it and it continued to comply with the needs of modern day land administrations.

However, due to societal needs, the complexities that needed to be accommodated, the cadastre kept growing to the point where it has not been able to perform all of its desired roles. The registration of 3D cadastral object is one such issue. Due to the complexity of the geometry, objects spanning one or more surface parcels, possible gaps in the vertical strata etc. have created both technical and legal challenges.

In a 3D context, parcels can be the surface parcel with a column of space above or below the surface of the earth as mentioned by (Stoter and van Oosterom 2006), or 3D strata titles as in the case of apartments, or parcels spanning several surface parcels as in the case of network objects (Figure 1). There are numerous other cases of a 3D parcel, but the significant issue here, is the departure from the dependence on surface parcels as the only means of spatially indexing the cadastral information.

Many land administration jurisdictions have recognized some 3D cadastral objects as separate entities and realized the importance of integrating this information into the land information system, but have not yet achieved the same measure of success as the surface parcel based data model. This is partly because of the plethora of alternative methods of constructing 3D objects, such as tetrahedrons (Ledoux 2009), constructive solid geometry (Ledoux 2009), regular polytopes (Thompson 2007, Thompson and van Oosterom 2007), extruding objects (Ledoux 2009) and other methods as described by the (ISO 19152 2009), as well as partly because of undefined data storage models and validation rules.

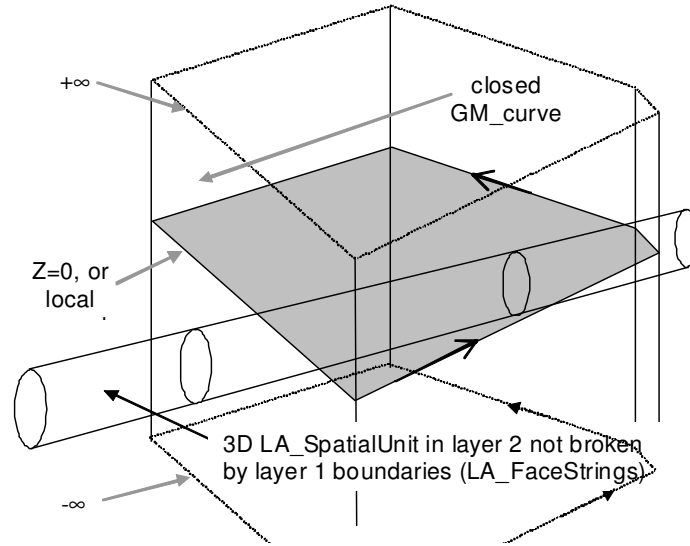


Figure 1: Network object spanning surface parcels (ISO/TC211 2009)

3. LEGAL PARCEL OBJECT

The legal parcel object is an interesting concept of fairly recent origins based on Kaufman and Steudler's Cadastre 2014 (1998), where the primary unit is a legal object with an associated physical parcel. In other words, an entity consisting of interests in land having a spatial dimension, in contrast to the physical land parcel model where the parcel is the primary object. The focus here is on preserving the homogeneity of the legal attributes while creating an expandable data model based on a spatially indexed object.

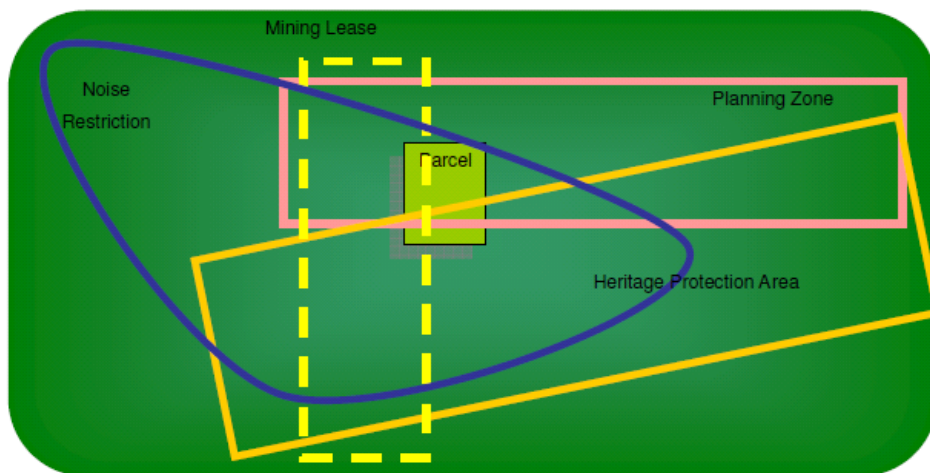


Figure 2: An example of non-parcel based interests (Bennett et al 2006)

Non-parcel based interests in land may not be restricted to a single parcel as in the case in (Figure 2) where several overlapping interests may co-exist along-with the ownership and spatial dimension and may be held separately to the title registration information. Combining these non-parcel based interests into a traditional cadastral system is difficult at this moment, whereas in a legal parcel object would be the building block of the system.

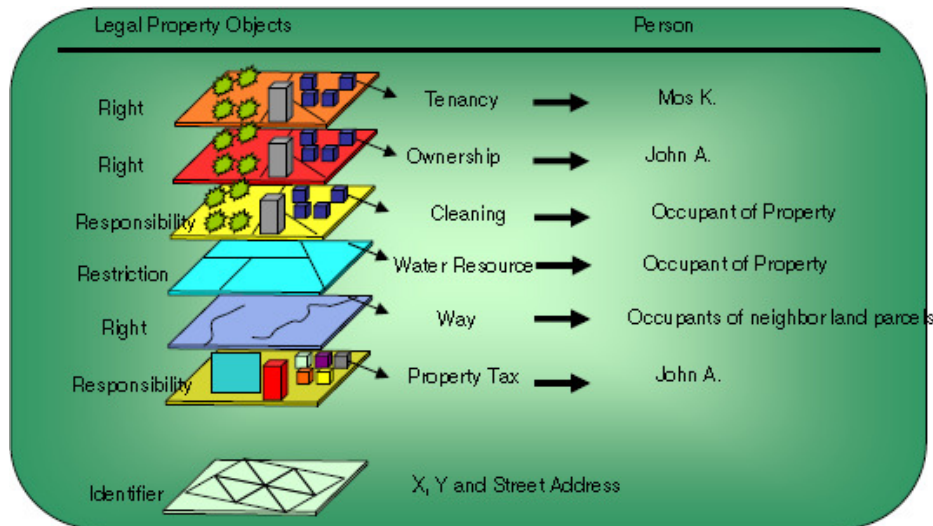


Figure 3: Spatially registering legal property objects (Kalantari 2008)

The legal parcel object data model allows all rights, restrictions and responsibilities, and commodities to be registered spatially in a holistic way (Kalantari 2008) (Figure 3). It provides an extensible model to accommodate new legislations, interests and commodities to be included in the system.

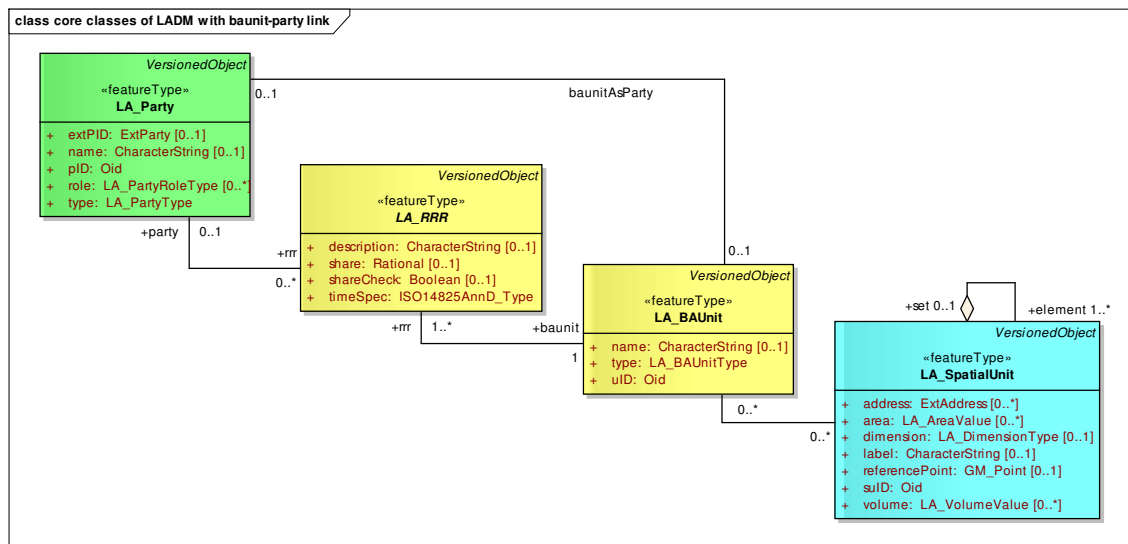


Figure 4: The four core classes of LADM (ISO/TC211 2009)

The ISO/TC211 2009 Land Administration Domain Model (LADM) has classes LA_Party, LA_RRR, LA_BAUnit and LA_SpatialUnit (Figure 4). According to the (ISO/TC211 2009)

the LA_BAUnit (basic administrative unit) is the administrative entity consisting of zero or more spatial units against which (one or more) unique and homogeneous rights (e.g. ownership right or land use right), responsibilities or restrictions are associated to the whole entity, as included in a Land Administration system.

The LA_BAUnit, along-with the classes LA_Party, LA_RRR is comparable with the legal parcel object with a spatial component LA_SpatialUnit. The parcel identifier in the LADM is based on the physical parcel which is a non-spatial entity, whereas in the legal parcel object model, the identifier is spatially enabled.

4. COMPARISON OF 3D CADASTRAL OBJECT MODELS

As the objective of this paper is to compare and analyse the applicability of the two data models to a 3D cadastral object, this section discusses the similarities and dissimilarities of the two data models for the various subsystems of a land administration. This section compares the 3D cadastral for the physical parcel model and the legal parcel model based on the land administration components as mentioned by (Dale and McLaughlin 1999), namely, Mapping, Registration, Land development and Land valuation.

4.1 Mapping perspective

Mapping traditionally involves collection of data from the field and either plotting the data as a paper map or entering them into a computerized database. For a 3D cadastre, most jurisdictions have adopted various ways to integrate the data into the existing cadastral system, so there is no homogenous approach at the moment. However, they are all based on the physical land parcel data model (Kalantari 2008).

4.1.1 Similarities:

There are various similarities in the approaches of the two data models for the mapping component. They both need data collected from some source, mostly from fieldwork, needs to have error checks and adjustments, validation, appropriate representation technique and storage geometry type (see section 2, para 4), data manipulation techniques and other database rules.

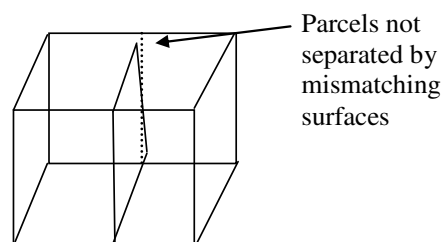


Figure 5: 3D representation of an incomplete subdivision

Two-dimensional cadastral parcels or surface parcels are relatively easier to validate to check for geometrical and topological consistency, while the 3D object is much more difficult to put through a vigorous and automated testing system. For example, to check if a 3D parcel

forms a closed figure as in (Figure 5 and Figure 6) is a much more complex task than to check if a 2D parcel is closed. These types of validation would be necessary for both the physical land parcel as well as the legal parcel object.

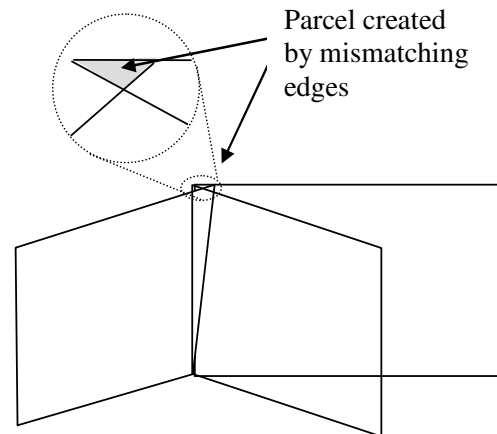


Figure 6: 3D representation of self-intersections creating spurious parcels

4.1.2 Dissimilarities:

In a strata situation, the physical parcel based model at present registers both the surface parcel as well as the strata title. However, in complex situations like in (Figure 7), there can either be a gap in the vertical space caused by the removal of 3D objects from a column of space, which is a difficult situation to handle for a physical land parcel based model, or gapless vertical partitions of columnar space which would be relatively easier to handle.

From a legal parcel object point of view, the spatial extent could be registered with the various strata as entities with varying legal attributes. The gapless vertical partitions would be handled quite well by the legal parcel data model; however, in the situation where there is a gap between the various unused strata, it would fail geometrical validation rules as columnar gaps would be unaccounted for and thus becomes more of a geometrical problem than a modeling issue. Thus, in 3D situations, although the legal parcel object model allows for a much smoother registration process, there is no advantage of one over the other for geometrical manipulation and validation.

4.1.3 Discussion:

As both the physical parcel model as well as the legal parcel model requires a spatial extent or a parcel, so, field measurements, error adjustments and validations and digital storage are necessary in both the data models. As far as mapping is concerned, for a 3D object, there is no added advantage or disadvantage in the two models, and thus it is not an issue on which model is a better representation of a 3D cadastral object.

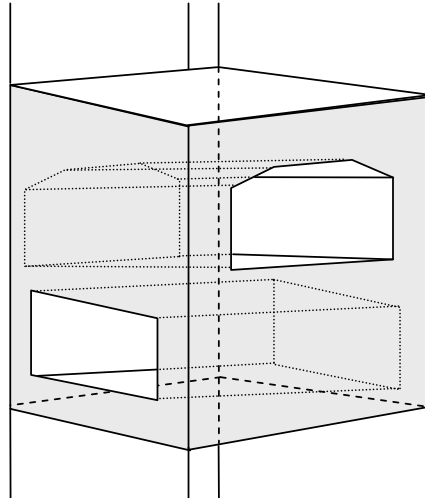


Figure 7: Complex shape formed when two network parcels cross below, and are excised from a 2D parcel

4.2 Registration and titling

Historically, registration as a process was utilized to record the ownership of a given parcel of land and the tax owed depending upon the type and productivity of the land. It gradually evolved into a system capable of recording the rights, restrictions and responsibilities, as well as other attributes such as caveats and mortgages etc.

The legal parcel model is capable of registering non-parcel based interests in land as well as the rights, restrictions and responsibilities, ownership information and spatial extents etc. Registration is the key area where legal parcels are better equipped to register all existing interests in land as well as being expandable to accommodate future interests.

4.2.1 Similarities:

Ownership: Registration of ownership (private, public, group etc) is at the heart of all land administration systems. The parcel based system which has been utilised historically, has been very capable of recording the ownership information of land. The legal parcel object should be able to perform a similar role with 3D objects recorded similarly in both the systems.

History and time series: History of the change in land attributes (shape, size, use, value, ownership etc) can be recorded in both the systems. Thus, for a 3D object, these attributes could be easily recorded provided the geometry is uniquely defined.

4.2.2 Dissimilarities:

Tenancy: Although physical parcel data models are capable of recording tenancy information, it can be stored better in a legal parcel data model as tenancy can be considered to be a form of rights (e.g. the tenant has security of tenure), responsibilities (e.g. the tenant needs to maintain the land) and restrictions (e.g. the tenant cannot sell the land or build on it without consent) for both the owner as well as the tenant.

Rights, responsibilities and restrictions (RRR): As with tenancy, although the physical parcel model can record the RRR of a land, the legal parcel would do a better job as the RRRs are the basis of the legal object (see Figure 3)

Interests and overlapping interests: All interests as well as overlapping interests (see Figure 2) can be recorded in the legal parcel object whereas according to (*Kalantari et al 2008*) the physical land parcel is not sufficiently flexible enough to accommodate these interests in land.

Spatially enabled identifier: The parcel identifier used in the physical parcel model is a non-spatial attribute which is used to uniquely identify as well as index parcels in the system. The legal parcel object uses spatially enabled identifier which has the added advantage of self validation as it can never be duplicated.

4.2.3 Discussion:

For a 3D cadastral object, the registration issue is very significant but is very much dependant upon the geometry. Attributes such as ownership, history and time series, tenancy, RRR, interests, etc can be easily recorded for a 3D cadastral object in both the physical parcel model as well as the legal parcel object. The spatially enabled identifier opens up various possibilities of uniquely identifying a 3D parcel as well as allowing for the unaccounted gaps in space after excision from a parcel (see Figure 7).

4.3 Land development

Most jurisdictions have a development plan or land use plan associated with land and may or may not be stored as part of the cadastral system. The objectives of land use planning may vary from sustainable development, to disaster management and the organizations responsible for maintaining the subsystem may be different to the one storing the cadastral data. However, because it is a component of land administration and an essential part of the life and transition of a parcel, so it must be related to a cadastral system.

4.3.1 Discussion

Information regarding present land use, secondary land use, indicative future planning, etc may or may not be part of the same database. However, it is relatively easy to store this information as an attribute of the parcel in the physical parcel data model. For a 3D object, defining and storing the land use of individual strata elements would not be as complex as storing the geometry, because all non-spatial information can easily be stored in separate tables.

Land use zoning or regulations can be considered to be either rights (right to use the land in a certain way) or restrictions (restrictions imposed by the administration disallowing certain kinds of land use). Legal parcel objects incorporate the rights, responsibilities and restrictions as part of the object definition, and so would be able to handle the land use information as an integral part of the creation of the object.

Thus, for a 3D cadastral object it makes no significant difference as to which model is used to store the land development information because both the systems are equally capable of storing the relevant information. However, 3D cadastral parcels provide the ability to cross-reference land use or planning restrictions that may relate to limitations on height or visibility.

4.4 Land valuation

Land valuation is a very important part of the cadastral system as it provides the basis for the fiscal administration as well as facilitates the transaction of land by providing a reliable and authoritative indication of the property market. Stamp duty collected during property transactions, as well as other duties such as land taxes and sometimes even rates depends upon recording the land or property valuation in land administration system. Although the value of a property is generally set by the prevailing property market, the mass appraisal of properties is often undertaken by land administration authorities to determine valuations of properties where no recent market information is available. The complexities of these valuation systems vary, however, a component of the appraisal or valuation process will often require the land or building areas in order to compute the final valuation.

4.4.1 Discussion:

As land value is a non spatial attribute, but not similar to rights, responsibilities or restrictions, so it might be stored as interests in land in both the models. It might be interests in land from both the owner's point of view as well as the administration point of view.

For a 3D cadastral object, the land value information can easily be stored in both the data models, so it does not make any significant difference as to which model is employed to store the data. However, with the increasing number of rights, responsibilities and restrictions associated with land, the quantification of the spatial extents of these RRRs through the use of 3D cadastral objects may facilitate the more accurate valuation of the property through a process of inclusion or exclusion which ever may be the case.

5. DISCUSSION AND FURTHER RESEARCH

The physical land parcel based models have been very successful in fulfilling the requirements of general land administration. But it has shown some inflexibility in integrating modern cadastral developments, interests and commodities. The legal parcel object on the other hand, has the potential to fulfil the requirements of integrating the existing and future interests and commodities.

The draft ISO/TC 211 19152 (2009) provides a middle ground by integrating physical land parcel models represented by LA_SpatialUnit to ownership and relevant parties (LA_Party), rights, restrictions and responsibilities (LA_RRR) and interests in land (LA_BAUnit). The data is organised in levels which provides opportunities for the inclusion of future interests or commodities.

Jurisdictions that retain the physical parcel based model need to look at improving the land administration systems by integrating the new interests and commodities into the land management systems, whereas, to change over to a legal parcel based model, issues ranging from technical, legal to administrative need to be investigated in detail.

From a 3D cadastral perspective, the primary issue at present is centred on the geometry (which representation technique to utilise, what to depict, how and what to measure, how to validate etc) and storage (what model to utilise, how to store and manipulate, how to validate etc). Once this is resolved and the structure of the geometry and feature manipulation techniques are finalised, it will assist in determining the optimum registration technique, so further investigation needs to be done to determine the technical, legal and administrative impacts as well as the flexibility to adapt to existing schemas and future innovations.

REFERENCE:

- Bennett R, Wallace J, Williamson I (2006) Managing rights, restrictions and responsibilities affecting land, Combined 5th Trans Tasman Survey Conference & 2nd Queensland Spatial Industry Conference 2006
- Dale PF, McLaughlin JD (1999) Land administration, Oxford University Press, New York
- ISO/TC 211, (2009), ISO 19152. Draft International Standard (DIS), Geographic information — Land administration domain model (LADM)
- Kalantari M (2008) Cadastral Data Modelling - A Tool for e-Land Administration, PhD Thesis, University of Melbourne
- Kalantari M, Rajabifard A, Wallace J, Williamson I (2008) Spatially referenced legal property objects, Land Use Policy 25
- Kaufmann J, Steudler D (1998), Cadastre 2014: A vision for a future cadastral system, Working group 1 of FIG Commission 7
- Larsson G (1991) Land registration and cadastral systems, Addison Wesley Longman Limited, Edinburg, England
- Ledoux H, Meijers M (2009) Extruding building footprints to create topologically consistent 3D city models, In: Urban and Regional Data Management, UDMS Annual 2009, Krek A, Rumor M, Zlatanova S, Fendel E (Eds). CRC Press
- Stoter J, van Oosterom P (2006) 3D Cadastre in an International Context, CRC Press, Taylor and Francis Group, Boca Raton, USA, ISBN 0-8493-3932-4
- Thompson RJ (2007) Towards a rigorous logic for spatial data representation, PhD thesis, Delft University of Technology, The Netherlands, <http://www.rgi-otb.nl/3dtopo/documents/RGI-011-52.pdf>
- Thompson RJ, van Oosterom P (2007) Mathematically provable correct implementation of integrated 2D and 3D representations. In: Advances in 3D Geoinformation Systems. Van Oosterom P, Penninga F, Zlatanova S, Fendel E (eds). Springer, Berlin
- Ting L and Williamson I (2000) Spatial Data Infrastructures and Good Governance: Frameworks for Land Administration Reform to support Sustainable Development. 4th Global Spatial Data Infrastructure Conference, Cape Town, South Africa
- Williamson I, Enemark S, Wallace J (2005) Sustainability and Land Administration Systems, Melbourne, Australia, Department of Geomatics, The University of Melbourne
- Zlatanova S, Stoter J (2006) The role of DBMS in the new generation GIS architecture, In: Frontiers of geographic information technology. S. Rana and J. Sharma (Eds). Springer, Berlin

BIOGRAPHICAL NOTES

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He is a surveyor with experience in the spatial information field since 1995. At present he is working as a scientist in the Department of Environment and Resource Management, Queensland. He is doing research at the University of Southern Queensland on 3D Cadastre.

Kevin McDougall

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Rod Thompson

He has been working in the spatial information field since 1985. He designed and led the implementation of the Queensland Digital Cadastral Data Base, and is now principal advisor in spatial databases. He obtained a PhD at the Delft University of Technology in December 2007.

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