3D Cadastral Parcels in South Africa – representing the third dimension in the South African cadastral system

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SUMMARY

Developments towards three-dimensional cadastral systems are the subject of numerous international research projects. In South Africa, there may be a need for the option to convey three dimensional rights, restrictions and responsibilities (RRRs), particularly in urban areas and above or below ground complex situations where overlapping or interlocking rights spaces exist. The cadastre serves as an important source of evidence of the location and extent of real property rights and therefore, must be comprehensive in its record keeping.

This paper emerges from a larger study (Humby, 2014) and firstly compiles a summary of the common drivers behind the research and development into 3D cadastres in the global arena. Subsequently, the ability of the current South African legal framework to provide for the accurate and comprehensive capture of 3D RRRs in the cadastral record is investigated. This ability is illustrated by describing two of the four case studies assessed in Humby (2014). Following this discussion, the need for research and development into the introduction of a third dimension into the South African cadastre is motivated according to the legal environment and the issues uncovered in the case studies.

Finally, a direction for further research within the South African context is recommended.

List of abbreviations

CTCC: Cape Town City Council
DBMS: Database Management System
DO: South African Deed's Office
PLS: Professional Land Surveyor
POS: Public Open Space
RRR: Rights, Restrictions and Responsibilities (associated with real property)
RSA: Republic of South Africa
SGO: South African Offices of the Surveyors-General

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1 INTRODUCTION

Land use and ownership has become a complex notion of overlapping rights. Increasingly, the requirement to tie land rights to a singular parcel in a two dimensional projection, is becoming an onerous burden. On the global front, land administration is being overhauled to accommodate these changes, legally, institutionally and technically, in the form of three-dimensional (3D) cadastres that fully and accurately represent the rights, restrictions and responsibilities (RRRs) in property. Rapid urbanisation and the resulting densification, particularly close to central business districts, leads to optimization of space in the vertical as well as horizontal dimensions both above and below the ground surface. Furthermore, high property value of these spaces leads to an increasing need for precise and accurate representation of property rights in 3D.

Many land surveyors in South Africa maintain that the current legislation and practice is adequate for recording these complex 3D cadastral rights. However, with technological advances in equipment that enable 3D spatial data capturing and management, and the adoption of these new techniques by built environment professionals, the generation of 3D cadastral parcels is increasingly possible. In keeping up with international trends and best practice, it may be time for South Africa to revise the legislation pertaining to land boundaries and to work towards a 3D cadastral legal tool. This paper focuses on exploring the need for 3D cadastral legal frameworks in South Africa, as informed by the internationally recognised drivers of change. At the outset, South African legislation pertinent to property rights is interpreted and critiqued according to its ability to serve the South African society by accurately recording 3D RRRs. Four case studies undertaken in greater Cape Town (Humby, 2014) provide some practical examples of the need, but due to restrictions of space, only two are reported here. These cases are set in urban environments since it is in this environment where the need is more keenly felt and "modern cities not only change the way we live, they change our concept of land" (Williamson et al., 2010: 43).

A qualitative mixed-methods approach was used in this research. Various key informants such as municipal officials, and land surveyors, both private and working at the Western Cape Surveyor-Generals Office (SGO), were interviewed to ascertain the problems with the current cadastral tools in the representation of complex rights. Documents such as building plans, sectional title plans, cadastral diagrams, court judgements, legislation and site visits were likewise important sources of data.

The conceptual property rights spaces are envisaged to be volumes contained by geometric bounding surfaces, rather than areas contained by linear (or curvilinear) boundaries. A planar assumption is made for the land surface over small areas, and so the representations contemplated

here are not true 3D property representations, but rather 2D plus 1D representations of 3D space. Just as the 2D projected cadastral diagram serves to deliver land tenure security for simple property rights, so the 2D plus 1D is likely to deliver land tenure security for more complex situations. This research does not consider the whole *solum*[1], but rather the land surface, soil and airspace developed, or reserved, for uses other than mining. Offshore property and non-linear boundaries are not considered in this initial exploration.

2 THE INTERNATIONAL NEED FOR A THIRD DIMENSION

Many developments in 3D cadastres internationally have been focussed on first world contexts while the predominant cadastral development in less-developed countries is focussed on improving land administration systems in line with the principles of good governance. The experiences of first world nations in 3D cadastral development are relevant to changing South African needs. This is because the South African cadastral system is advanced in comparison to developing nations and the context of 3D cadastral development in South Africa is currently focussed on developed urban areas.

Stoter (2004 and Stoter et al., 2013) recognised that the shortfalls of the Dutch Kadaster were the lack of geometric representation of both 2D and 3D rights and the inability to separate property units from the surface parcel. In the case of Norway, it is noted that the pressure for vertical property rights is increasing and that property units are becoming more common due to improved and cheaper building techniques and technologies (Onsrud, 2003; Stoter, 2004; Valstad, 2006). The Norwegian government recognised the need for separation of under- and above-ground property units in order to allow for mortgage bonds to be raised against these properties. It is believed this will stimulate investment and an increased market value for such properties, which will lead to an increased property tax base. Similar drivers for change exist in Sweden with the added complication that apartments could only be owned by a housing association (El-Mekawy et al., 2014; Stoter, 2004). In Queensland, Australia, and in British Columbia, Canada, it is noted that unprecedented economic growth encourages the development of rights objects and interests in land defining complex horizontal divisions of ownership previously unseen (Karki et al., 2010; Karki, 2013; Pouloit et al., 2010; Stoter, 2004). Israel has noted the changing land administration system (LAS) needs associated with urbanization and pressure on land (Benhamu et al., 2002; Felus et al., 2014; Jaljolie et al., 2016; Shoshani et al., 2005).

3 THE SOUTH AFRICAN LEGAL CADASTRAL ENVIRONMENT

The concept of ownership, as conceptualized in the development of early property law, encapsulated the entire 3D wedge extending from the centre of the Earth into space. However, this is not practical and ownership is reduced by restrictions and responsibilities, such as the rights of other legal persons and the statutory restrictions prescribed by government (Stoter, 2004). Instead,

[1] The rule of *cuius est solum* extends ownership of the surface parcel in a 3D pyramid from the centre of the earth out through the crust and extending to infinity (Badenhorst et al., 2006 and Mostert, 2012).

the relationships in respect of property (proprietary relationships, or RRRs) (Mostert and Pope, 2010) are delimited by surface boundaries leading to the concept of the proprietary unit. This proprietary unit is represented in 2D on a cadastral diagram as the land rights parcel.

A distinction must be made between the land rights parcel documented in the current cadastre as an erf, and the legal parcel object that is the subject of concern of this research (Karki et al., 2010). The parcel is the cadastral record of the 2D area on the Earth's surface and attached to it are implied RRRs in height and depth. The legal parcel object shall be known as a "property unit" and refers to the volumetric space to which RRRs are attached that may include construction units (a man-made spatial object) and/or space units (Stoter, 2004). The term "space unit" shall be used to describe a rights volume that includes only undeveloped space, below or above the ground (hence the use of "space unit" rather than "airspace unit", without limits defined by current construction units.

The cadastral system in South Africa involves two principal governmental organisations, the SGO and Deeds Office (DO), with registered Professional Land Surveyors (PLSs) and Conveyancers playing crucial roles in the operations of the system. These compile, process, approve and register the title deeds and diagrams necessary to secure property rights into two independent systems, the Deeds Registry and the cadastre respectively. The cadastral system is underpinned by the principles of good governance (Hull et al., 2013; Lemmen et al., 2015; Palmer et al., 2009) that require an accessible, transparent register of rights in property. Additionally, the record must be comprehensive, up-to-date and accurate, providing evidence of RRRs to increase tenure security within society. On the other hand, if these principles are not adhered to, a lack of lucidity in the register can result in legal difficulties and a conflict of interests. The agencies responsible for land registration records are the Surveyors-General of the nine provinces as well as 10 Deeds Registry Offices (Riba, 2010). Furthermore, it is claimed that the cadastral information system is based on a system of "accurate delineation of the ownership rights" (Riba, 2010, n.p.). The question remains as to whether this delineation is being achieved in the South African land administration system in the light of vertical development complexity.

3.1 Developments on/under/above the land

In South Africa, ownership and real property rights are tied to the surface parcel. All permanent alterations (constructions) to this land are implicitly included in the ownership right by accession as derived from Roman Law (Stoter, 2004). The parcel is the registerable entity and the constructions are not themselves separately registerable (Stoter, 2004). As a result, it is impossible to own a construction unit separately from the land it is attached to. As a result, South African legislation has been developed and different procedural routes have been created to cater for the current variety of real property situations. A further complication is that in most cases there is no legal requirement to indicate, within the deed or on the diagram, constructions on the surface parcel. Only in the case of a sectional title scheme (see 3.2), or if a construction unit is associated with a servitude right, is it required to indicate the rights and their extent in the diagram and deed.

3.2 Limited real rights tools to capture 3D property units

As mentioned, stratification of property is accomplished using limited real rights. Employing one of several legal tools creates these rights (Humby, 2014). These include either adding a condition clause in the title deed to describe and legalise the situation, creating a servitude over the surface parcel, defining an encroachment agreement, employing the Sectional Title Act or registering a long lease. None of these legal tools allow for the complete severance of the property unit from the land parcel. Therefore the unit-holder's tenure is ever dependent on the erf it falls above or below.

A servitude is a registered limited real right belonging to one person in the property of another person. The servitude holder is entitled to benefit from the property through some use or enjoyment or to benefit from the property by prohibiting the owner from exercising one or more of their rights of ownership (Mostert and Pope, 2010). Servitudes are registered against the property of the servient tenement in favour of a juristic person (personal servitude) or a dominant tenement (property in the case of a praedial servitude). Public servitudes grant entitlement to the public over the property. These rights are not granted in favour of a particular erf or person, and therefore there is no defined dominant tenement meaning that they are personal servitudes (Mostert and Pope, 2010). Regardless of the type of servitude, differentiation, and possible stratification, of ownership over the surface parcel takes place (Stoter, 2004).

The inherent limitation of the servitude legal tool is that there is always one dominant party. Additionally there is no independence of tenure and both parties are bound by the obligations that the servitude enforces. Servitude is a minor right in comparison to ownership. Therefore, each party holds fewer rights than usual ownership. At times a single servitude is not sufficient to capture the property unit in its entirety and a number of servitudes have to be created. This can result in complex cadastral and title deed records and a situation that is difficult for land administrators and interested parties to understand.

A sectional title scheme (Sectional Titles Act No 95 of 1986) allows for the subdivision of a building into different property units (volumes) that are capable of separate ownership in a combination of sectional freehold and ownership in undivided shares of common property. This meets most residential ownership needs in high-density buildings and was the first adaptation of Republic of South Africa (RSA) legislation to allow for ownership of volumetric space.

The restrictions of absolute ownership and use rights over the *solum* are, in addition, affected by statutory and common law. Conditions of encroachment, building restrictions, servitudes, airspace restrictions, rights of support and other aspects may restrict the manner and means of excavation below, and building above, the land surface. Where there are property rights held by another party who is not the owner of the surface parcel, much attention is paid to the vertical dimensions of these rights extents. Examples of these are underground parking garages, tunnels, underground or overhead walkways, overhanging sections of buildings, and basements. It is the duty of a PLS to capture these property units accurately and this can become a complex task when a servitude is extended over multiple erven and/or forms complex shapes.

The Survey Regulations (Land Survey Act 8 of 1997) define the minimum accuracies in fieldwork that must be achieved by the PLS and the procedure to be followed when registering diagrams. Regulation 21 deals with servitude diagrams. When registering a servitude or lease that is not situated at ground level, the elevation of that area must be represented in metres above mean sea level (as determined from named control points) and this should be reflected on the servitude or lease diagram (Simpson et al., 1973).

4 FIRST CASE STUDY OF MALAWI HOUSE, SIMON'S TOWN

4.1 Case description

Malawi House, 136 St George's Street, Simon's Town (see Figure 1) is a Sectional Title Scheme established in 2009 on Remainder Erf 992 Simon's Town.[2] The scheme itself is not complex and the sections, common property and exclusive use areas are clearly represented on the cross-section plans of each floor of the building. The balcony of this scheme, however, is encroaching over two erven, St. Georges Street and Erf 1019 Simon's Town.[3] These are road reserve and public area respectively (see Figure 2 and Figure 3 for clear representation of the encroaching area).

Figure 1: (Left) The street view of Malawi House, Simon's Town showing the encroaching balcony and pillars. Right: A side view of Malawi House, Simon's Town. (Photographs: L Humby 26/06/2014)

The current owners of Malawi House bought the property in a dilapidated state in 2000 with the intent to renovate. There was a damaged canopy structure that has now been replaced by the balcony. Originally, the owners applied for permission from the Municipal Council to construct the encroaching balcony in terms of Zoning Regulations that create air and underground rights over Council-owned land. A Council representative originally granted this permission. However, this representative was soon replaced and the permission was withdrawn, because the balcony would prevent the planned widening of St. Georges Street in the future. During that time, unfortunately, the balcony had been built and in January 2003 the Council requested that the balcony be demolished. The Malawi House owners decided to take the matter to court and in October 2003 a long and expensive legal battle ensued.

[2] As per Sectional Title plans S.G. Diagram No. D844/2008.
[3] S.G. Diagram No. D 7490/57

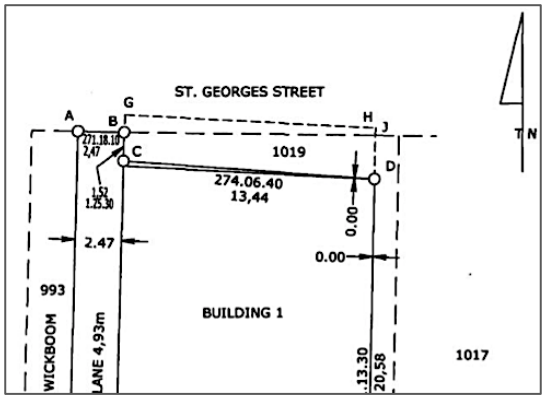

Figure 2: (Left) An aerial view of Malawi House showing the Remainder Erf 992 Simon's Town and balcony roof encroaching over Erf 1019 Simon's Town and into St George's Street. (Image: City of Cape Town: City Map Viewer)

Figure 3: (Right) Extract from S.G. No. D 844/2008 Sheet 2 of 6 showing the encroaching balcony GHJDCB over St George's Street and Erf 1019, Simon's Town.

The case was finally put to rest in the High Court of South Africa in 2007 (Hawes & others v MEC, 2007). After three years and much private and state expense, the owners of Erf 992 Simon's Town were granted a Notarial Deed of Servitude of Encroachment[4] over the erf in perpetuity. The Erf 1019 Simon's Town is registered as the servient tenement and the Remainder Erf 992 Simon's Town is the dominant tenement.

The Notarial Deed[5] gives a summary of the final judgement and the conditions of the agreement, including the condition that the owners enter into an 'agreement of non-compensation' with the City of Cape Town. In other words, if road widening were to be found necessary, the owners would not be compensated for costs of demolishing the balcony. The public is given the "right of thoroughfare over the servitude area at the ground level at all times".[6]

4.3 Issues inherent to the current solution

If better 3D cadastral tools had been available, three possible issues could have been avoided, or their impact could have been reduced. Firstly, there was wastage of private and state resources in reaching a settlement. Secondly, this solution does not give the balcony owners full rights to that space. They are dependent on the servient tenement and the contractual obligations as set out in the Notarial Deed. Finally, although it can be argued that the balcony constructed provides shelter to the public and is therefore beneficial, this solution required the public to relinquish full ownership rights of the road and the road reserve. Therefore the public is now limited by reduced rights that fall servient to Erf 992 Simon's Town.

5 SECOND CASE STUDY OF THE STANDARD BANK BUILDING, ROGGEBAAI

[4] Title Deed No.: T292/10/1803
[5] T292/10/1803 (2010)
[6] T292/10/1803, 2007: 4

5.1 Case description

The Standard Bank building (see Figure 4) is located on Hertzog Boulevard, Cape Town over three adjacent Erven: 144, 146 and 147 Roggebaai.[7] Figure 5 illustrates how the building relates to the property boundaries. A single legal person owns the erven and, therefore, the buildings. The landowner wishes to construct, in the future, an elevated parking garage with supporting columns between the two buildings on Erven 144 and 147 Roggebaai. The proposed structure would encroach over Remainder Erf 192 Roggebaai, which is Public Open Space (POS) and falls under Cape Town City Council (CTCC) jurisdiction.

Figure 4: The Standard Bank building on Hertzog Boulevard, Cape Town (Source: Google Earth 3D Warehouse Model)

5.2 Solutions put in place

This case study is a fascinating example of a how the South African legal system registers an airspace property to reserve future building rights over that space, while the holders of this property unit do not own a physical construction or land associated with the property.

Once permission to encroach had been granted by the CTCC, the Professional Land Surveyor assigned to the job created four servitudes[8] to encapsulate the required volume for the planned overhang and support columns (refer to Figure 6 below). The exact wording extracted from the S.G. Diagram No. 776/2014 creating the servitudes is as follows:

1. *"The figure A, B, C, D, E, F, G, H represents a Building Rights Servitude Area and extends from a height of 21,70m to a height of 48,90m above mean sea level*
2. *The line JD represents the north western boundary of a Support Solumn Servitude Area 0,50m wide and extends to a height of 21,70m above mean sea level*
3. *The line DE represents the north eastern boundary of a Support Columns Servitude Area 1,05m wide and extends to a height of 21,70m above mean sea level*
4. *The line EK represents the south eastern boundary of a Support Column Servitude Area 0,50m wide and extends to a height of 21,70m above mean sea level."*

[7] S.G. Diagram. No. 8867/1952
[8] S.G. Dgm. No. 776/2014

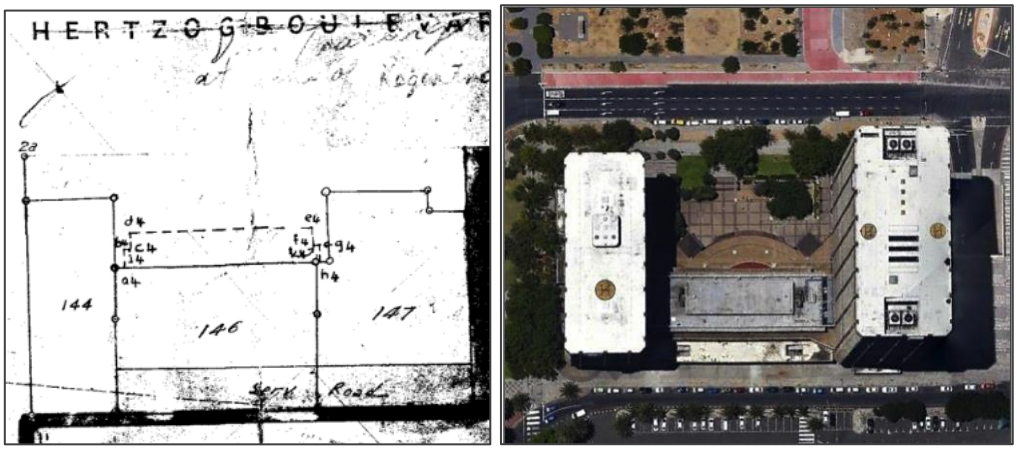

Figure 5: Left: a portion of S.G. No. 8867/1952 to illustrate the layout of the erven in relation to each other. Right: An aerial view of the Standard Bank building on Hertzog Boulevard (Source: Google Earth)

Firstly, a Building Rights Servitude Area (note this is a 2D description) was established over Remainder Erf 192 Roggebaai in favour of Erven 144, 146 and 147 Roggebaai using the corner beacons A, B, C, D, E, F, G, H. This area was then 'projected' into a volume that captures the necessary airspace property unit by stating on the servitude diagram that it "extends from a height of 21.70 m to a height of 48.90 m above mean sea level".[9] Similarly, further servitude areas along the lines JD, DE and EK, were created to include the support columns necessary to the future construction and these were extended in height up to 21.70m above mean sea level as required by Regulation 21 of the Land Survey Act 8 of 1997.

5.3 Issues inherent to the current solution

As in the case of Malawi House, the proposed overhang and support columns that will be associated with this property unit will encroach over public open space (POS), and the POS becomes the servient tenement. Once again, although the balcony will afford the public shelter, the ownership rights of the public over that land are reduced. The servitude is for airspace, but is not independent of the surface parcel and is inherently tied to the servient tenement, Remainder Erf 192 Roggebaai.

[9] S.G. Dgm. No. 776/2014

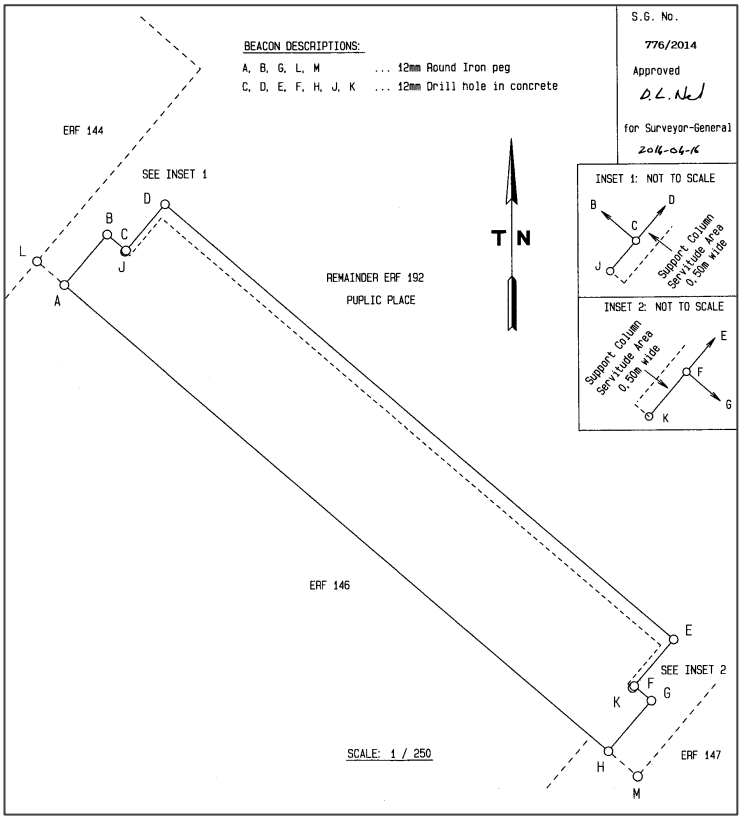

Figure 6: A portion of S.G. No. 776/2014 to illustrate the 2D representation of the servitude created.

The immediately obvious problem with the 2D representation of this building rights servitude is that the situation may be represented with greater clarity in 3D. This is especially true in this case because there is no physical construction to which the property unit can be related, and the unit is intangible. The dominant tenements hold rights over a significant volume of airspace and, if not recorded adequately, this may lead to a loss of intelligibility in the cadastral and LAS records.

6 THE NEED FOR A SOUTH AFRICAN 3D CADASTRAL SOLUTION

As societies change, so should the legal system and, when necessary, the concept of ownership. The legal system should suit the context in which it acts and also the functions that it must perform (Badenhorst et al., 2006). The objective of the cadastre is to reflect a complete, up-to-date record of real property rights in South Africa. It has been recognised, in South Africa and internationally, that growing urban populations are increasing the need for development space. This and the advancement in building technology and tools have resulted in higher building densities and multilevel, overlapping, ownership constructs. Table 1 lists the drivers for research, development and implementation of forms of 3D cadastres as identified from international research articles. The research has identified that all but one of these drivers are present in South Africa (see Table 1), showing that the country is aligned with global trends and drivers with respect to 3D cadastres. The need that is not common in South Africa is ‘Apartments not supported’. In South Africa, apartments

are supported in the cadastre and the legal system by the Sectional Titles Act 95 of 1986, albeit that the rights are captured in two-dimensions.

The South African case studies discussed in this paper illustrate the shortcomings of the current legislation and regulations in adequately registering real property RRRs. Boundaries of RRRs are reflected in the form of 2D parcels. However, these RRRs are implied in 3D, defining a volumetric object rather than a 2D area. The RRRs volumes overlap and interlock with each other and with the surface parcels, forming volumetric property units similar to a 3D puzzle. Therefore, as the true 3D situation is simplified to be represented by the current 2D cadastre, valuable information is lost. Stoter puts the issue at hand as:

> "a person who queries the cadastral register wants to obtain insight into the legal status of the situation. However since constructions are not registered as themes and since rights are mostly not explicitly related to physical objects in the real world, the accessibility of information on the legal status of 3D situations is poor" (2004: 43).

Table 1: A Summary of the internationally identified drivers towards the implementation of a 3D cadastre.

Internationally Identified Drivers towards 3D Cadastre:	South African Drivers:
Urbanisation & the need for "high density" spaces	✓
New RRRs objects & interests in land	✓
Horizontal division necessary	✓
Apartments not supported	✗
A single, transparent, up-to-date register	✓
Interdepartmental access to consolidated records	✓
Unambiguous record of property object	✓
Independent ownership from surface parcel	✓
Lack of geometric representation	✓
Security for mortgage	✓
Increase in value of property	✓
Stimulate built environment sectors	✓
Improved building techniques = cheaper & easier to go vertical	✓
Improved technology to capture 3D information	✓

Additionally, constructions are included as part of the 2D parcel inherently, by accession, and the nature of their ownership differentiated from the surface parcel in 3D space is lost in registration. This is likewise a simplification of reality and, although it is not problematic when there is only one owner of the parcel and building, problems arise when trying to register a construction or part thereof separately from the land it is built on, above or below. In South Africa, it is only possible to sell different parts of a building to different persons if that building has been sectionalised under the Sectional Titles Act 95 of 1986. The research indicates that the current legal tools available to register a property unit may not conclusively allow for the complete severing of the unit from the surface parcel. This is problematic, because only a completely independent unit holds a full bundle of RRRs and is as valuable as a surface parcel.

This is illustrated in both the Malawi House and Standard Bank case studies, where none of the legal persons involved walked away with independent ownership rights of the property units. In the Malawi House case, ambiguity of the property record led to a drawn-out dispute and wasted resources. It is an important case study, because the related court judgement (Hawes & others v MEC, 2007) could influence future decisions where overlapping volumetric rights conflict, as well as informing statute law development. This is concerning, because the judgement ruled that the public surrender their full ownership rights over the surface parcel and retain only a servitude right of way. This is a minor right in comparison with ownership and therefore, should not be the advised way forward for solving overlapping 3D property situations.

The Standard Bank case study used a number of servitudes to encapsulate the volume needed for a future building right. This was an adequate approach, however, the airspace unit is difficult to visualize and this is likely to reduce the interpretability of the records.

The authors are also aware of other South African cases (Humby, 2014) in which *no* legal tool has been used to define the construction, and they are not registered in a deed or represented a diagram and can only be assumed to form part of the surface parcel's ownership column. This is problematic, because it creates a legal grey area in which a construction does not have a defined owner and responsibility has not been assigned. This can lead to unnecessary conflict. The solutions available to register 3D RRR spaces in a variety of cases all exhibit fundamental issues and limitations (Humby, 2014).

For complex 3D structures, the current South African land tenure record reflects, as illustrated, inaccessible, misleading or erroneous data because of the lack of a unified centralised cadastre. The case studies show that using the currently available legal tools, South Africa may be unable to comprehensively record RRRs in 3D. The current parcel-based cadastre is not attaining all the objectives it is required to fulfil (Karki et al., 2010); the country is falling short of its objectives and some of the globally recognised principles of good governance.

7 CONCLUSION

It has been shown that the South African cadastre is limited with regards to registering 3D RRRs and the overlapping and interlocking 3D property units are difficult to translate into a 2D cadastre while retaining clarity in the records created. Therefore, the register is not succeeding in its objectives of producing an accessible, transparent and precise public record that protects the RRRs in property. The cadastre serves as an important source of evidence of the location and extent of proprietary units and therefore, must be comprehensive in its record-keeping. A lack of clarity in real property rights leads to the possibility of erroneous and inaccurate records that may result in disputes that cost time and money. To avoid conflict situations, the cadastre, and its foundational legislation, should be adapted to wholly capture property rights and perform its purposes adequately in the context of the changing property needs in South Africa.

Following this publication, a second paper will be written that explores how current legislation and practice could be amended to accommodate a 3D cadastral product. The manner in which the 3D cadastral model could be implemented and used is discussed in a further paper, looking specifically at the possible representation of a 3D model in the cadastre. This will include investigation and analysis of the impact on both built environment professionals and users of the cadastral system. It will also investigate the necessary capacity development.

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BIOGRAPHY LARA HUMBY

Lara Humby was born in 1986. She graduated with a B.Sc. (Geomatics) specialising in land surveying from the University of Cape Town in 2014. The initial project work on 3D cadastral representation was conducted by her for her final year research project. She now works for the Department of Rural Development and Land Reform, but currently is seconded to various professional practices to complete her articles period in order to register as a Professional Land Surveyor. She is also a master's student in Geomatics at the University of Cape Town in order to take this research further. She is supervised by the second author.

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Jennifer Whittal is an Associate Professor in the Geomatics Division at the University of Cape Town. She obtained a B.Sc. (Surveying) and a M.Sc. (Engineering) specializing in global navigation satellite systems from the University of Cape Town. In 2008, Jenny obtained her Ph.D from the University of Calgary applying critical realism, systems theory and mixed methods to a case of fiscal cadastral systems reform. She is a Professional Land Surveyor and lectures advanced surveying and land law. Research interests are land tenure and cadastral systems with specific interest in sustainable development and resilience in land holding for the poor, historical property holding, and cadastral issues in the coastal zone.

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