Development of a 3D cadastre over South Africa

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1 SUMMARY

This paper proposes a framework for implementing an authoritative 3D cadastre in South Africa, anchored to a unified geodetic foundation, ITRF for horizontal control and a vertical position consistent with the IHRF, to enable the registration and management of volumetric rights, restrictions, and responsibilities (RRRs). Drawing on international exemplars (e.g., New Zealand, the Netherlands, Israel), the study outlines the technical, legal, and institutional prerequisites for transitioning from 2D registration to 3D land administration. It positions the 3D cadastre as the legal core within a broader 3D City Model that also comprises physical/BIM–GIS layers for planning, valuation, and infrastructure coordination. A metropolitan pilot concept for Cape Town is advanced to operationalise the approach, clarify roles between the national Land Tenure System (LTS) and municipal Property Management System (PMS), and test end-to-end workflows from survey evidence to authoritative publication. A staged roadmap, datum realisation, legislative and regulatory updates for volumetric parcels and 3D survey plans, CIS upgrades for 3D QA/QC and dissemination, governance separating authoritative legal content from indicative physical layers, and phased pilots with cost–benefit evaluation, is proposed to de-risk national adoption while preserving legal certainty and enabling smart-city and digital-twin use cases.

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2 INTRODUCTION

The purpose of this paper is to propose the development of a 3D cadastre for South Africa. A 3D cadastre would enable explicit, legally robust registration and management of the spatial extents of rights, restrictions, and responsibilities (RRRs), thereby modernise South Africa's land tenure system and advancing the national cadastre toward a digital-by-design information environment. The current cadastre is fundamentally two-dimensional (2D), defined by a horizontal coordinate reference realised in the International Terrestrial Reference Frame (ITRF), while the vertical component is treated separately. In contrast, a modernised system should integrate both horizontal and vertical components in a unified three-dimensional (3D) framework aligned with international standards. Achieving this objective necessitates the realisation of a national, geoid-based vertical datum through the International Height Reference Frame (IHRF) so that the South African coordinate system is realised in true 3D rather than as separable 2D (horizontal) and 1D (vertical) elements (Mphuthi & Odera, 2021).

Implementing a geoid-based vertical datum will further accelerate the transition to a 3D digital cadastre by enabling rigorous height control across cadastral datasets and ensuring consistency with geodetic infrastructure. Embedding the national vertical datum in land titles and related legislation will, in turn, facilitate complete validation of positional information, improve 3D data management and dissemination practices, and support the registration of multi-level property rights (e.g., tunnels, underground parking, and volumetric units). These capabilities are most urgently required in dense urban environments characterised by overlapping and interlocking developments, but they are equally applicable to the countrywide modernisation of the cadastral system. International efforts demonstrate feasibility and pathways to implementation: New Zealand, the Netherlands, and the Russian Federation have undertaken prototypes or operational steps toward 3D cadastres, leveraging modern technologies while maintaining legal integrity (Vandysheva et al., 2012; Guo et al., 2013; Gulliver et al., 2016).
Beyond legal registration, recent scholarship highlights broader public-sector and economic benefits associated with transitioning from 2D to 3D representations. Pickett & Woodlief (2024) explore the potential of "3D economic cadastres" to improve real-property valuation and planning by integrating elevation, viewshed, and volumetric characteristics into valuation models, thereby enabling more accurate taxation and more transparent decision-making. They emphasise the central role of GIS and related 3D analytical technologies in collecting, analysing, and visualising spatial data, including for public engagement and accountability, and present use-cases that illustrate adaptability to diverse governance and environmental contexts (Pickett & Woodlief, 2024).

Transitional strategies are also essential, particularly where legacy data and resource constraints limit immediate, comprehensive 3D adoption. Harper (2024) argues for a "Fit-For-Purpose" (FFP) approach that incrementally adapts existing 2D cadastral databases to support 3D modelling and digital twins. This strategy recognises the widespread shortage of reliable height information for existing titles, the prohibitive cost of re-surveying at scale, and the value of standard datums, pragmatic control, and affordable technologies (e.g., scanning and LiDAR) to progressively enrich and anchor 3D extents. Insights from Australia and Indonesia show how FFP 2D cadastres can form an effective foundation for 3D systems and city-scale digital representations, provided that geodetic reference zones and datum realisations are carefully specified and consistently applied (Harper, 2024).

Operationally, the integration of 3D legal spaces with authoritative spatial infrastructure requires both capable information systems and clear regulatory pathways. Experience from Israel underscores how enabling legislation and purpose-built platforms can institutionalise 3D practice. Following the 2018 enactment of a 3D land registration law, a comprehensive 3D Cadastral Management System was developed to manage 3D subdivision plans within a coherent data environment comprising a 3D cadastral database, quality-control engines, CAD-to-GIS migration tools, a 3D viewing environment, and a web-based management system. The Israeli case demonstrates that, in dense urban contexts, integrating legal models with geospatial technologies can substantially improve precision, efficiency, and the overall standard of cadastral administration (Sivan & Felus, 2024).

Taken together, these international examples and emerging methods provide a compelling rationale and a set of implementable building blocks for South Africa's transition to a 3D cadastre. This paper argues for a unified geodetic foundation (ITRF horizontally and a geoid-based IHRF vertically), legislative and regulatory provisions for volumetric parcels and 3D survey plans, and an interoperable technical ecosystem capable of sustaining authoritative 3D registration. The sections that follow outline the status of the current South African cadastre, develop the conceptual and regulatory requirements for 3D cadastre implementation, and point to a metropolitan case (Cape Town) as a candidate environment in which to pilot 3D integration for land administration and smart-city applications.

In this paper, a 3D cadastre is defined as an authoritative land administration layer in which legally recognised rights, restrictions, and responsibilities (RRRs) are associated with geometries that can represent their full spatial extent in three dimensions. The term 'authoritative' is used to distinguish legally binding cadastral content from indicative 3D city-model layers (e.g., BIM-GIS representations) that support analysis and service delivery but do not in themselves confer registrable rights. Throughout, 'volumetric parcel' refers to a registered legal space that is bounded in X, Y, and Z and can be uniquely identified, validated, and disseminated.

Contributions of this paper

- A South Africa-specific framing that links 3D cadastral implementation to a unified geodetic foundation (ITRF for horizontal control and a geoid-based vertical position aligned to the IHRF).
- A description of how above- and below-surface land-related rights are currently handled within an essentially 2D registration paradigm, and why this creates ambiguity in dense urban settings.
- An analytical framework (evaluation criteria) for pilots that separates authoritative legal content from municipal property-management and digital-twin layers.
- A Cape Town case example (3D Development Management Scheme envelopes) to illustrate a pragmatic pathway for piloting 3D legal-space workflows and testing CIS readiness.

3 CURRENT SOUTH AFRICAN CADASTRE

The South African cadastral system constitutes a core element of the national land administration framework, providing the authoritative record of land ownership and the associated rights, restrictions, and responsibilities. By furnishing reliable boundary and tenure information, it enables legal certainty in property transactions, supports valuation and taxation processes, and underpins the efficient operation of real-estate markets. Institutionally, the system is administered by the Department of Rural Development and Land Reform, National Geomatics Management Service (NGMS) branch, whose mandate encompasses the regulation, maintenance, and dissemination of cadastral records for public, professional, and governmental use.

Historically, the cadastre has evolved from its Dutch colonial origins through a succession of statutory and technological reforms that progressively strengthened the legal, procedural, and spatial bases of land governance. The transition from manual records to digital platforms has markedly improved data integrity, accessibility, and auditability, while expanding the scope for integration with other land information systems. These advances have enhanced the robustness of survey control and boundary definition practices and have supported the standardisation of documentation and workflows across jurisdictions.

The trajectory of cadastral development has been closely interwoven with shifts in South Africa's socio-political landscape. Beyond its function as a register of private rights, the cadastre has served as an instrument for implementing land policy objectives, including programmes aimed at addressing historical dispossession and facilitating redistribution. In this respect, the system has provided a spatially explicit, legally secure foundation for the administration of state land, restitution parcels, and tenure reform initiatives, thereby contributing to broader goals of equity, sustainability, and development.

In its contemporary form, the cadastre operates as more than a transactional register. It supports spatial planning, infrastructure delivery, environmental management, and public administration by supplying authoritative parcel geometries and tenure attributes for multi-sectoral decision-making. As urbanisation accelerates and the built environment becomes increasingly vertical and complex, the demands on cadastral information systems extend to richer, multidimensional representations and tighter couplings with geodetic and geospatial infrastructures. This creates both an opportunity and an imperative to align cadastral data models and workflows with emerging three-dimensional practices, without compromising the legal integrity and institutional reliability that are the hallmarks of the existing system.

Managing above- and below-surface rights in a predominantly 2D register

Although South Africa's property law recognises that rights may extend above and below the surface, the spatial index of the cadastre remains primarily planimetric. In practice, multi-level and sub-surface situations are managed through specialised instruments that reference the underlying 2D parcel while describing vertical extent in plans and legal descriptions.

Sectional title provides the clearest operational example of multi-level ownership: ownership is created in defined parts of a building ('sections') together with joint ownership in common property, supported by registered sectional plans and associated schedules. Servitudes and other limited real rights are typically created and registered by notarial deeds and are recorded against affected titles; their spatial definition may be depicted on diagrams/plans or described textually, but is not consistently represented as validated 3D geometry in the national cadastral information system.

Similarly, certain resource-related rights may be separated from surface land ownership and administered under sectoral legislation. These arrangements demonstrate that South Africa already administers layered rights, but the lack of an authoritative 3D geometric representation increases ambiguity where legal spaces intersect or overlap (e.g., tunnels beneath private parcels, basement parking extending beyond building footprints, or servitude corridors intersecting multi-storey developments). A 3D cadastre is therefore not a conceptual departure from existing rights, but a modernisation of how their spatial extents are defined, validated, and published.

4 THE CONCEPT OF 3D CADASTRE DEVELOPMENT

A transition to a 3D cadastre requires that cadastral boundaries be anchored to a rigorous vertical reference and that volumetric parcels be modelled, surveyed, and registered in three dimensions (e.g. Sectional Title Plans). Practically, this entails embedding cadastral geometry within a precise elevation framework, preferably a geoid-based vertical datum aligned to IHRF, so that heights and volumes are geodetically consistent with the ITRF-realised horizontal component. This unified reference enables unambiguous positioning of complex, multi-level properties (e.g., tunnels, underground parking, strata units, air rights) and supports interoperable integration with other geospatial datasets.

Institutionally and legally, the cadastre comprises two inseparable components: a legal component (land registration and administration of rights, restrictions, and responsibilities) and a spatial component (survey control, cadastral mapping, and geo-referencing). Advancing to 3D, therefore, requires complementary reforms on both fronts. On the legal side, enabling provisions are needed for the creation and registration of volume parcels, together with regulations prescribing the content and standards of 3D survey plans and their relationship to existing titles. On the spatial side, technical specifications must define height systems, tolerances, data formats, and visualisation/validation requirements for 3D submissions within authoritative coordinate reference frames.

The limitations of 2D representation are most acute in dense urban cores, where overlapping, interlocking constructions render planimetric parcels inadequate to depict the full extent of property rights recognized in law. While the legal framework acknowledges ownership above and below the surface, operational registration remains essentially 2D. A 3D cadastre resolves this mismatch by capturing the full spatial envelope of rights, linking legal descriptions to 3D geometries that can be validated against survey evidence and displayed within modern geographic information systems.

Realising these benefits depends equally on digital infrastructure. The modernisation of the cadastral information system (CIS) should proceed in tandem with 3D cadastre reform so that authoritative 3D data can be ingested, validated (including vertical control), managed, and disseminated. This includes support for standardized exchange of 3D geometries, integration with base elevation models and vertical datums, and publication workflows that serve both professional and public users without compromising legal integrity. Together, these legal, geodetic, and digital measures provide a coherent path from today's 2D register to an authoritative, interoperable 3D cadastre for South Africa.

Analytical framework and evaluation criteria for 3D cadastre pilots

To ensure that theoretical propositions are directly tested in practice, this paper evaluates proposed 3D cadastre implementation steps against five criteria that are applicable to metropolitan pilots and scalable nationally:

- Geodetic referenceability: the ability to position, reproduce, and transform 3D legal spaces in an ITRF/IHRF-consistent reference.
- Legal interpretability: clarity of how the represented 3D object relates to registrable RRRs, precedence, and conflict resolution.
- Data integrity and validation: topological correctness (watertight volumes where applicable), QA/QC rules, and auditability.
- Information-system readiness: CIS capability to ingest, store, version, and disseminate authoritative 3D objects at scale.
- Governance separation: explicit separation between authoritative legal geometry (cadastre/LPO) and indicative physical or municipal layers (city model/PMO).

Evidence from South African local government supports a 3D city-model framing in which the 3D cadastre's Legal Property Object (LPO) forms the authoritative legal layer and the Property Management Object (PMO) extends it with function-specific, non-registrable RRRs for municipal land use, development, and valuation tasks. In the case study conducted by Humby (2021) on City of Cape Town, the PMO is explicitly defined as the LPO plus additional non-registrable RRRs; the broader 3D city model is treated as an extension of the 3D cadastre comprising the collection of PMOs in a 3D urban data model. This municipal perspective is operationalised through a Property Value Chain and mapped PMS data flows that show how departments contribute property information into the PMO.

Introducing 3D is associated with clear benefits (better decision-making, analytics, valuation support, and infrastructure/utility management) but also reveals silos, data-sharing and data-quality constraints, and uneven capability across agents. An ideal trajectory is to establish authoritative 3D records within the cadastre and allow municipalities to consume them. Humby (2021) identifies gaps in national GIS authority and in the definition of the LPO that drive Property Management work-arounds and duplication; consequently, municipalities may need to lead selected 3D implementations until the Land Tenure System's capacity and standards mature. For this paper's roadmap, a Cape Town pilot that anchors PMO volumes to an ITRF/IHRF-consistent, geoid-based vertical datum, with explicit governance distinguishing authoritative (legal) from indicative (physical/BIM-GIS) layers, offers a credible path to operational 3D land administration; a staged cost–benefit assessment should precede scaling.

4.1 Case Study: Cape Town's 3D Development Management Scheme (DMS) Envelopes as a Foundation for 3D Digital Cadastre Implementation

4.1.1 Overview of the Development Management Scheme and the 3D DMS Envelopes

The City of Cape Town's Geospatial Section, in collaboration with the Development Management Department, initiated a project to develop city-wide 3D DMS envelopes to spatially represent real properties' rights, restrictions, and responsibilities (RRRs) as per the City's Development Management Scheme as defined in the City of Cape Town Municipal Planning Amendment By-law 2025 (MPBL 2025).

The Development Management Scheme defines the specific allowable use and development of a property according to its designated zone. That use and development is defined by horizontal setbacks from the property boundary that define the 2D DMS footprint, and a vertical limit on development height defines the 3D DMS envelope. These are spatial definitions of use and development; however, until now, the City did not have these regulations represented spatially. This left the rules open to interpretation, potentially prolonging Land Use and Building Development applications, and introducing ambiguity that leaves room for dispute.

By representing the DMS zoning provisions (including the boundary setbacks, height restrictions, coverage ratios, and floor factor) in 2D and 3D in the City's GIS, the City created a legally interpretable and visual dataset that enhances visualizations, analysis, decision-making, and policymaking. The limits imposed on every property by the local government's (municipality) legislation are the primary definition of how a property owner may use or develop their property in the third dimension; thus, this paper purports that the DMS Envelope dataset can serve as a foundation for future 3D cadastre implementation for land parcels in the

City of Cape Town. By defining the 3rd dimension or vertical component of a property's RRRs, land management and tenure security are improved (Humby, 2021).

4.1.2 Building a 3D DMS Envelope Dataset: The Data Sources

The following City of Cape Town datasets were utilized in generating the 2D DMS Footprints and 3D DMS Envelopes:

a) Land Parcel Datasets (2D): These polygon feature classes hold the cadastral information of all registered properties in the City, and include the zone code of the erf as an attribute. The zone codes include the Transport zones that were used to identify roads as needed for street setback lines. These datasets are under the custodianship of Development Management and Valuations, and the cadastral data is sourced directly from the registered Surveyor-General diagram and the registered Title Deed information, respectively.
b) Servitude and Split Zone Layers (2D): These layers were used to assist in defining the 2D DMS footprint in cases where the property over which the footprint is generated has a registered servitude or overlay conditions.
c) Ground Level Map (GLM2019) (3D): This is a legally gazetted elevation surface derived from the 2019 Light Detection Ranging (LiDAR) survey (2 – 3 pts/m² density, ~20 cm vertical accuracy), consisting of a 5m Digital Elevation Model (DEM) and 2m Contour datasets. The 2019 LiDAR data is referenced to the Land Levelling Datum (LLD) height reference surface. The GLM2019 provides the City with an official 3D surface defining the existing ground level (EGL) from which the 3rd dimension and/or vertical components (for example, maximum building height) are derived.

4.1.3 Building a 3D DMS Envelope Dataset: The Methodology

a) Generating 2D DMS footprints:
   The 2D DMS footprints were generated using ArcGIS Pro models built within ESRI's *ModelBuilder* and Python scripting environments. ArcGIS models are workflows that string together sequences of geoprocessing tools, feeding the output of one tool as input into another. *ModelBuilder* can be thought of as a visual programming language for building workflows (Esri, 2025). For every registered land parcel within the City, a 2D DMS footprint representing the boundary setback was generated.

   The DMS zoning rules were modelled for each zone and subzone category (for example, Single Residential (subzones: SR1-SR2), General Residential (GR1-GR6), General Business (GB1-GB7), Mixed-Use (MU1-MU3), and General Industrial (GI1-GI2)). The models took into account street setbacks, common boundary setbacks, maximum development height, maximum coverage, and floor factors.

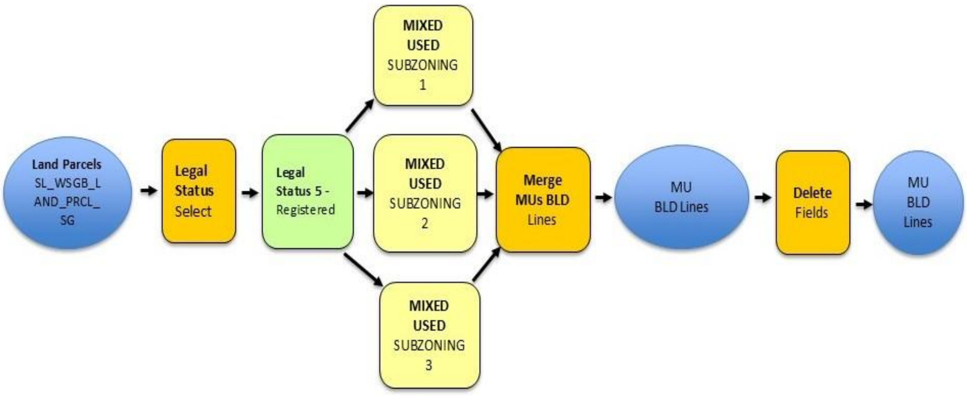

Figure 1: Mixed-Use Zoning ArcGIS Model used to generate Mixed-Use 2D DMS footprints.

The outputs were standardised into a city-wide 2D DMS footprint Esri feature class representing permissible buildable areas within each registered land parcel as 2D polygons. The dataset is stored in the City's Planning and Building Development Management (PBDM) enterprise geodatabase for centralised access by City employees.

b) Generating 3D DMS envelopes:
   Another set of ArcGIS models was used to extrude the 2D DMS footprints into 3D DMS envelopes (3D RRRs volumes) by applying the maximum building height restrictions as per the Municipal Planning Bylaw (MPBL 2025). To ensure consistency across the City and with the MPBL (2025), the 3D extrusion was measured from the GLM2019; the legislated definition of the existing ground level (EGL) surface for the City of Cape Town.

   The outputs are standardised 3D volumetric models that spatially represent the maximum permissible developable volume of each registered land parcel within the City according to the DMS zones, and inclusive of building line setbacks and height restrictions.

4.1.4 3D DMS Envelopes: The Results and Examples

The ArcGIS models enabled the automation of generating 2D DMS footprints and 3D DMS envelopes for all the registered parcels across 2,700 km². The utilisation of the GLM2019 elevation surface for spatially mapping the 3rd dimension ensured vertical accuracy (±30 cm DEM tolerance). These 3D DMS envelopes enabled a City-wide realistic visualisation of the permissible developable volume, supporting planners (including the Municipal Planning Tribunal dealing with high-interest and complex land use and development applications), developers, and the public in assessing whether a proposed development complies with zoning regulations more effectively. Below are examples of the application of both 2D DMS footprints and 3D DMS envelopes:

Figure 2: Single Residential and General Residential 2D DMS footprints illustrating the spatial extent of property RRRs using a 2D polygon, denoting the street and common boundary building setback lines.

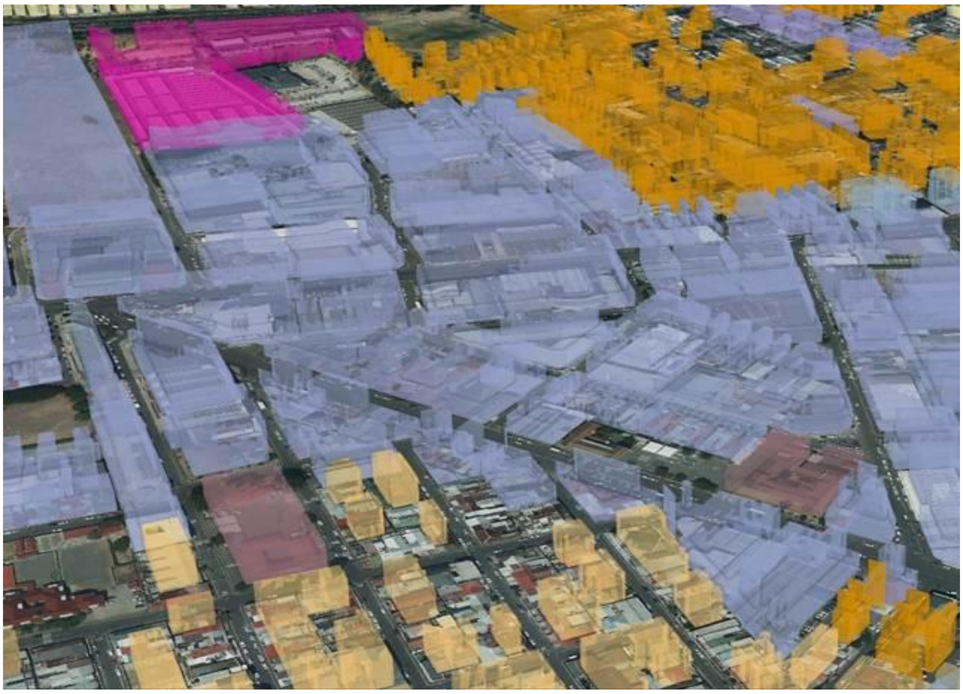

Figure 3: Residential, commercial, and industrial 3D DMS envelopes illustrating the spatial extent of property RRRs in 3D. The permissible developable volume is defined with reference to street and common boundary building setback lines, as well as maximum height restrictions.

Figure 4: General Residential (GR4) 2D DMS footprints showing the spatial extent of property RRRs. The permissible developable area is defined with reference to street and common boundary building setback lines.

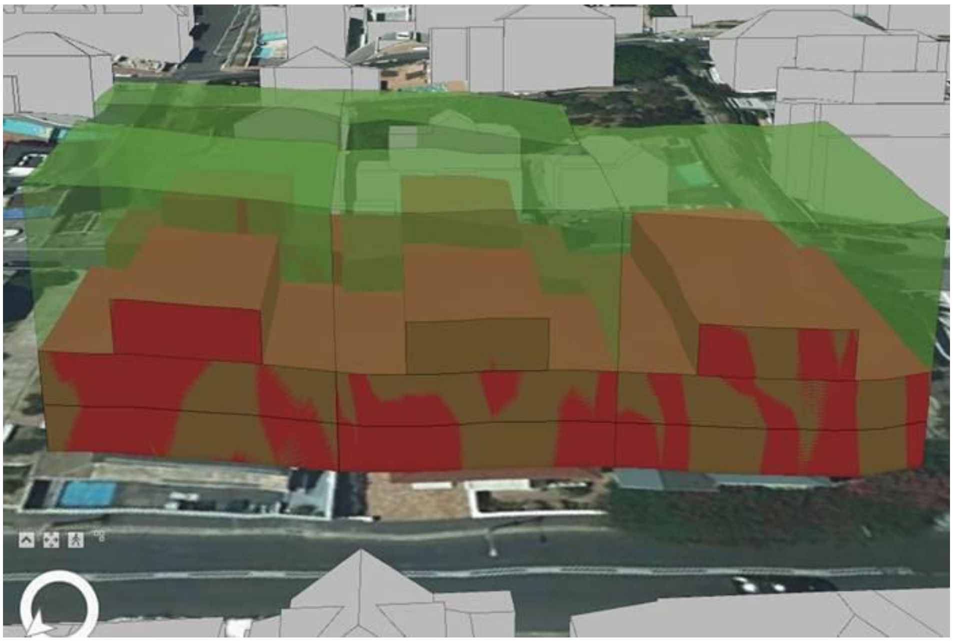

Figure 5: General Residential 4's 3D DMS zoning envelopes illustrating the spatial extent of property RRRs in 3D. This representation clearly defines the permissible developable area, including street and common boundary building setback line, maximum building restrictions, as well as the permissible floor space.

Case-study synthesis against the evaluation criteria

The Cape Town DMS envelope implementation provides a pragmatic test-bed for 3D cadastre development. First, geodetic referenceability is partially satisfied through consistent use of the City's legislated Existing Ground Level (GLM2019), but national scaling requires a geoid-based vertical datum that is consistently realised and published. Second, legal interpretability is strong for municipal RRRs (development rights and restrictions), yet the envelopes are not registrable cadastral objects; they therefore illustrate the distinction between the authoritative legal cadastre (LPO) and municipal property-management objects (PMO). Third, the workflow highlights the importance of data integrity: overlaps, incomplete transport parcels, and subjective rule interpretation directly propagate into the derived 2D and 3D outputs, motivating stricter CIS-based validation and authoritative source data controls. Fourth, the city-wide automation demonstrates feasibility at scale but also exposes computational and skills constraints that must be addressed in a national CIS upgrade programme. Finally, the project underscores governance separation: publication of 3D envelopes for transparency and decision-support is valuable but must be clearly labelled and versioned so that it does not create legal confusion with registered rights.

4.1.5 Organisational Processes:

This project required close coordination between GIS specialists, experienced planners, and system administrators. A cross-departmental working group was established, comprising members from the Geomatics Branch, the Development Management Business Systems Branch, and Professional Town Planners from the Land Use Management Department. The Geomatics team, together with Business Systems, led the GIS modelling, process automation workflows, and dataset creation, while the Planners provided guidance on zoning regulations interpretations and validations. These collaborative efforts ensured accurate interpretation and translation of planning regulations from the Municipal Planning Bylaw into the City's GIS environment.

4.1.6 Challenges and Successes:

There were numerous challenges encountered, and some are outlined below:

- Overlapping registered land parcels posed a major challenge, as they resulted in duplicate 2D DMS footprints. Additionally, unsurveyed and unregistered transport parcels led to the incorrect application of street boundary setback lines. Overall, these issues caused inaccuracy in the 2D DMS footprint layer. The Land Parcel dataset must be complete and topologically correct to ensure the models produce an accurate and reliable 2D DMS footprint layer, which the 3D DMS envelopes depend on.
- The Development Management Scheme regulations are complex, and aspects of the rules can be subjectively applied to a property. This does not lend itself to automating the modelling of these rules. In this case, the team was forced to ignore some development regulations that were impossible to automate and flag the property for further investigation by a city official. Ideally, the DMS should be overhauled to simplify the regulations and create a clear code that can be used

to guide land use and development, as well as form the basis of DMS footprints, envelopes, and, finally, a 3D Cadastre.

- Hardware limitations in handling larger geospatial datasets, especially when extruding 2D DMS footprints to 3D DMS envelopes, presented a challenge. The processing required demands a sophisticated computational machine.
- Limited Geospatial and GIS skills within the Development Management Department and the City at large translate into scarce human resources available, requiring extensive training and support, for this type of work.

There were, however, successes as outlined below:

- Successfully automated the generation of 3D DMS envelopes across the entire City of Cape Town, enabling the 3D spatial extents of property RRRs to be captured, validated, integrated with existing data, visualised, and made available for use in various applications. Consequently, creating a foundational dataset for a future 3D cadastre implementation for land parcels (defining their 3rd dimension).
- The availability of a 3D DMS zoning layer enhances transparency, reduces ambiguities, misinterpretations, and disputes in land use and building development applications between developers, planners, property owners, and the public.

4.1.7 Recommendations for National Scaling:

The City of Cape Town's initiative in automatically modelling the DMS zoning regulations into their GIS environment demonstrates that 3D DMS zoning envelopes can serve as a foundational dataset for 3D cadastre implementation, moreover, defining the 3rd dimension for land parcels. If this initiative is to be extended nationally:

- To ensure consistency throughout the country, a standardised vertical reference (Geoid-based vertical datum) through the IHRF is needed, so the South African coordinate system is realised in true 3D rather than as a separable 2D (horizontal) and 1D (vertical) elements (Mphuthi & Odera, 2021)
- There is potential for other South African local authorities to replicate the City of Cape Town DMS workflows based on their Municipal Planning Bylaws. To follow suit, local authorities would need to develop and legislate a 3D surface to define Existing Ground Level within Land Use and Building Development Management. This is critical for defining the maximum developable height that, in turn, defines the 3D RRRs of a property.
- The South African legislative framework must support the definition of property RRRs in a 3D digital environment as a spatial object and define how the spatial object is incorporated into and managed within the cadastral survey system. A spatial object would describe (within specified accuracy standards) the size, shape, and extent of property RRRs as a 'watertight' 3D volume (Gulliver et al., 2017).

5 CONCLUSION

South Africa's migration from a two-dimensional register to an authoritative 3D cadastre is necessary and feasible, but it requires a disciplined alignment between geodesy, law, and information systems. The central geodetic requirement is a unified reference: horizontal control realised in the ITRF must be complemented by a geoid-based vertical position aligned to the IHRF so that cadastral heights and volumetric extents are reproducible and interoperable across survey, GIS, and BIM environments.

The Cape Town 3D Development Management Scheme (DMS) envelope programme demonstrates the value of representing legally interpretable RRRs in three dimensions for transparency, planning decisions, and dispute reduction, while also exposing practical constraints that must be addressed before a national 3D cadastre can be implemented. In particular, topological issues in source parcel data, subjective elements of development rules, and uneven computational and skills capacity directly affect the reliability of derived 3D volumes and therefore motivate a strengthened QA/QC regime and authoritative source controls.

Accordingly, this paper recommends a staged national roadmap: (i) publish and operationalise an IHRF-consistent vertical datum and transformation policy for cadastral use; (ii) update survey and registration regulations to enable volumetric parcels and define examinable 3D plan standards; (iii) upgrade the cadastral information system for 3D ingestion, validation, versioning, and dissemination; (iv) formalise governance that distinguishes authoritative cadastral legal geometry (LPO) from municipal and physical/digital-twin layers (PMO and BIM-GIS); and (v) execute phased metropolitan pilots with explicit evaluation criteria and cost-benefit assessment before scaling.

By treating 3D cadastre development as an institutional and technical programme - not only a data-model change - South Africa can preserve legal certainty while enabling modern urban land administration capabilities in rapidly densifying environments.

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Siphiwe Mphuthi is a Senior Lecturer in the Division of Geomatics at the University of Cape Town (UCT), and a registered Professional Land Surveyor & Sectional Title Practitioner. He is a seasoned professional with a rich academic foundation in Geomatics and a well-established track record spanning various facets of this dynamic field. With more than 14 years of dedicated experience, he consistently showcased exceptional leadership and technical prowess, enabling him to thrive in diverse roles, including lecturing, consulting, and overseeing extensive geospatial projects. His educational journey includes a Ph.D. in Geomatics, an M.Sc. in Engineering specialized in Geomatics, and a B.Sc. in Geomatics from UCT. His primary research niche revolves around the domain of physical geodesy, with a particular focus on gravimetric geoid modelling and the establishment of vertical datums. This encompasses the modernization of both horizontal and vertical geodetic reference frames, as well as the meticulous adjustment and analysis of gravity data.

Khumeleni Makungo is a registered Professional Land Surveyor with SAGC and a GISSA member, with a Master's in Geoinformatics from the University of Pretoria, awarded with distinction. His postgraduate research focused on the application of deep learning for feature extraction, specifically building footprint detection from aerial imagery and LiDAR using Mask R-CNN. He is currently Acting Principal GIS Analyst at the City of Cape Town, where he leads the Geospatial section, research and development on geospatial innovations, including 3D City Models, LiDAR quality assurance, and process automation. His academic and professional interests span geospatial artificial intelligence, 3D urban modelling, urban digital twins, and the integration of advanced spatial data to enhance urban planning and governance frameworks.

Lara Röttcher is a registered Professional Land Surveyor with a Master's in Geomatics from the University of Cape Town. Her postgraduate research investigated 3D cadastre and the representation of property objects in 3D City Models, contributing insights into how cadastral systems can better support land administration. She is currently Head of GIS & Surveys in the Property Transactions Department at the City of Cape Town, where she manages cadastral and geospatial functions that underpin municipal property governance. Previously, as Principal GIS Analyst, she led the City's Geospatial Section and initiated key 3D projects, including zoning models and foundational 3D datasets. Her work focuses on embedding 3D geospatial data into urban governance and decision-making.

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