First 3D Cadastral Registration of Multi-level Ownerships Rights in the Netherlands

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Key words: 3D Cadastral Registration, Architectural Mdels (BIM), 3D Deed, 3D Land Registration

SUMMARY

This paper reports on the first 3D cadastral registration of multi-level ownerships rights in the Netherlands, which was accomplished in March 2016. It is the result of a study that was undertaken from 2013 to 2015 to determine how insight about multi-level ownership can be provided in 3D by the cadastral registration. The solution was sought within the existing cadastral and legal framework, with the aim to build a more fundamental solution for 3D cadastral registration in the future, based on practical experience and involving the stakeholders. The 3D cadastral case presented in this paper is the new combined structure of the city hall and underground railway station in the town of Delft. The complex contains the new city hall, the railway station, the underground platforms and railway tunnel, several technical installations as well as the underground bicycle-parking. The paper presents the procedure that was followed to secure the ownership rights before the construction was completed; the translation of ownership described in the deeds into legal volumes based on the architectural drawing of the buildings; and, finally to create the 3D visualisation of the 3D rights involved and to register a deed that contains the 3D visualisation in the interactive 3D PDF format. The paper then evaluates the registration to obtain insights for an improved 3D cadastral registration. The main conclusion is that in some situations a 3D approach has important advantages for cadastral registration over a 2D approach. It requires further study on how to implement the solution in a standardised and uniform way from registration to querying and updating in the future and from an informal to a formal (i.e. legally binding) registration process.

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1. INTRODUCTION

Property rights in land are in many jurisdictions registered on 2D parcels. However, almost everywhere it is possible to entitle a person a right to a volume whether it is for the ownership of a physical construction or for air space (for example a wind right relating to a wind mill or wind turbines, an easement to protect a right of view or an apartment right). The legal and technical practices used to create such 3D legal entities and to register them in the land registers and cadastre vary from jurisdiction to jurisdiction. More and more jurisdictions provide the possibility to describe the 3D spatial extent of such legal volumes in registered deeds or title documents. But until now these 3D descriptions are often paper-based: e.g. volumetric plans that show isometric views to depict 3D spatial units or building plans that show sketches of building numbers, locations, levels and layout (Karki and Thompson, 2014). These traditional, analogue systems of registration do not support the storage of 3D data, nor the automated validation of 3D data nor the interactive visualisation of the 3D entities. 3D solutions have recently been developed for apartment units, for example in Spain (Olivares García, 2011). But these do not provide solutions for multi-level ownerships not related to apartments or condominiums.

The limitations of a 2D parcel-based land administration have recently been addressed in the Netherlands where a first interactive 3D visualisation of multi-level rights was registered in March 2016.

Multi-level property rights in the Netherlands have been in existence long before the start of the Dutch cadastre (1832) and is established via limited real rights on the 2D parcel such as easement, right of long lease and right of superficies. To be able to sufficiently represent the spatial extent of each right in the cadastre as prescribed by the "specialization principle", 3D ownership situations are projected on a 2D parcel map and 2D parcels are divided into small parcels to be able to register the ownership of objects above and below the surface. This results sometimes in unclear fragmentation of parcels, as illustrated in Figure 1.

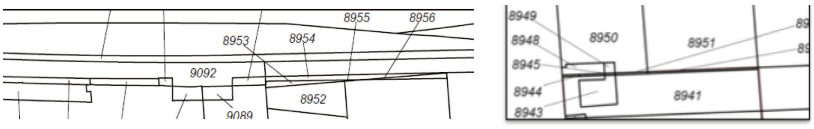

Figure 1. Registration of multi-level ownership on 2D parcels results in fragmented parcel patterns

At the moment the legal situation is created, all stakeholders have to agree on the registration and therefore only minor problems are faced. The main challenges arise in future transfers of multi-level property rights, when the involved parties (buyer, seller and others such as a mortgage bank) need to reconstruct the 3D ownership from the 2D cadastral map and the deeds registered in the land register. The difficulties of reconstructing the 3D legal situation from the description in deed (in words and accompanying 2D maps), in combination with the 2D parcels boundaries on the cadastral map have been experienced a few times already in the Netherlands as can be understood when looking at the complex parcel patterns in Figure 1.

To address this issue, the Netherlands Kadaster has started a study to improve the registration in such cases (Stoter et al, 2013). The implementation of the proposed improvements consists of two phases.

The first phase started in 2012 and finished with the first 3D cadastral registration of a real world case in March 2016 (and the evaluation thereof). The solution of the first phase was sought within the limitations and possibilities of the existing legal and cadastral frameworks and aimed at gaining experience in the challenging domain of 3D cadastre where technical possibilities on the one hand and legal and cadastral needs on the other, interact. The aim was to provide a solution for the problem that rights on 3D volumes can be established for decades (even centuries) but not made visible. Therefore, a procedure was developed to accept 3D representations of legal volumes in 3D PDF format as part of the deed. With the recently established acceptance of the digital registration of deeds in the Dutch land registers, the registration of a 3D visualisation of multi-level rights in the form of a 3D PDF has become possible.

The second phase is research in progress and builds on the lessons learned from the first phase. It comprises the study how to accommodate the explicit registration of rights and restrictions limited in 3D and the actual inclusion of these volumes in the registration, to enable complete validation and even better 3D data management and dissemination.

In 2014 the first circumstance arose to test out the procedure developed in theory during the first phase on a real life example: the building complex combining the new city hall and the underground railway station in Delft. For the 3D registration, the Kadaster has worked closely together with the Municipality of Delft and the 3D Geoinformation group of Delft University of Technology. The 3D visualisation was designed by Mecanoo Architects based on the BIM data generated in the design and construction phase. The notary firm of Houthoff Buruma has issued the certificate for the deposit in the Land Registry.

This paper reports on this registration. Section 2 presents the case. In section 3 we describe the process that was followed to secure the ownership rights of the complex in the cadastral registration; to create the 3D visualisation of the 3D rights involved; and, to register a deed that contains the 3D visualisation in the interactive 3D PDF format (which can be viewed here: https://www.youtube.com/embed/vFMoH-2r7xo). Section 4 evaluates the registration resulting in questions for further research. We finish with conclusions in Section 5.

2. THE 3D CADASTRE CASE

The 3D cadastre case of this paper is the new combined structure of the city hall and underground railway station in Delft. The complex contains the new city hall, the station, the underground platforms and railway tunnel, several technical installations as well as the underground bicycle-parking.

This building is located in the heart of the Delft Railway Zone project. This project involves the replacement of the existing railway viaduct through the city center by a railway tunnel and offers scope for the redevelopment of an urban area of around 24 hectares. The complex forms actually the center of the project. The location is the transportation hub for Delft and the surrounding area, where train, tram and bus lines come together. Below the bus platform, an underground parking provides space for 5.000 bicycles. Apart from the train station at ground level and below, the building hosts the new municipal offices of the city of Delft, with working spaces for 800 civil servants on the ground floor and three floors up. The building was constructed in a period of two years, from 2013-2015, within the agreed time frame and within the financial budget. Since the site is located in the middle of town, construction logistics were of essence. Smart building principles were used and the construction of the steel framework was done as much 'prefab' as possible. See for a two month time lapse: https://www.youtube.com/watch?v=tHW6HfQZS20. The Station opened on 28 February 2015.

The total of the Delft Railway Zone covers an area of 24 hectares. The project consists of:

- a 2,3 km tunnel, replacing a partly elevated railway, running along the historic city centre of Delft;
- underground train platforms and station;
- station hall with shops at ground level;
- municipal offices for the city of Delft on four levels;
- 2 underground bicycle parkings (5.000 spaces) (and 2.700, under construction);
- underground car parking (650 spaces);
- new public space, including a park on top of the tunnel and a non-navigable canal for water storage above the car parking;
- urban redevelopment, mainly of former railway yards.

Thus, the Delft Railway Zone project is a combination of infra-structure, mainly railroad, and urban redevelopment. It is a transit-oriented urban development. The Dutch ministry of Infrastructure and Environment and the municipality of Delft are the main financing partners.

The 3D cadastre case presented in this paper covers only a small part of the total project. The combined new Railway Station and the new City Hall, together with the underground platforms and railway tunnel, several technical installations as well as the large underground bicycle parking, appeared to be a very suitable choice for the first real world 3D cadastral registration that we had worked out in theory in Stoter et al (2013).
The multi-layered construction is located on a relatively small piece of land. It combines property rights of three parties in the project: the municipality of Delft as owner of the land and the City Hall, NS Real Estate as owner of the Station Hall with shops and installations

and ProRail/Railinfratrust as owner of the tunnel and the platforms, see Figure 2. ProRail/Railinfratrust is the Dutch railroad infrastructure company, and NS is the Dutch railroad company for passenger transportation. ProRail/Railinfratrust and NS are separate legal entities.

Figure 2. The building complex of Delft station, with left the ownership situation and right a picture of the situation above ground

3. THE REGISTRATION PROCEDURE

This section describes the procedure that was followed to create the 3D representations of the legal volumes and to register it via a 3D deed (i.e. a 3D PDF registered as official document in the Land Register).

For this building complex, six legal volumes have been established:

- Railway hall (NS Vastgoed);
- Travellers area (Railinfratrust B.V.);
- Elevator/stairs (NS Vastgoed);
- Technical installations (NS Vastgoed);
- Tunnels (Railinfratrust B.V.);
- Municipality Delft: everything that is left.

The first five property rights were established with a right of superficies. The municipality owns the land and therefore it owns all space that is left after subtracting the volumes for the rights of superficies. Each right can contain more than one object (space) and it can also overlap several ground parcels.

The first step of the registration secured the real rights at the start, before the 3D registration was realised. The reason to not start with the 3D deed, was the condition that the transfer of rights should have been finished upon completion of the first construction phase. Because the 3D registration was the first one ever accomplished, the stakeholders did not want to run a risk of any delay due to the new way of registration.

After all stakeholders agreed that they would register the involved 3D property rights via a 3D deed, the rights were established for the different parts and described in a deed (in wordings and 2D drawings) that was recorded in the Land Register, see Figure 3. In this process also new ground parcels were formed, i.e. original parcels (still reflecting the historical ownership

situation before the existing houses and other constructions that have been demolished for the Delft Railway Zone project) were consolidated and subdivided in order to specify the different accumulation of rights of the new complex.

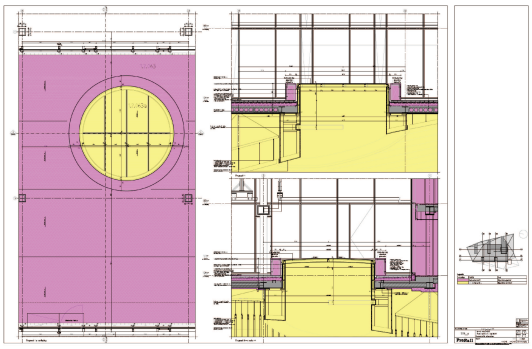

Figure 3. Registration of 3D rights by 2D description in deed

In the second step, the architect converted the 3D drawing of the construction (the building information model, BIM) into the six legal volumes based on the already registered deed in close consultation with all stakeholders. Several researches have studied how to use BIM for modelling 3D ownership rights. See for example El-Mekawy (2014) and Atazadeh et al (2016). And also at Kadaster similar research was done, see Stoter et al (2013). In this step the deed with the 2D drawings and accompanying description was studied and legal volumes with 3D geometries were constructed.

It was decided to represent the office building of the municipality, even though the total space owned by the municipality is much larger. The total space owned by the municipality contains all space left after the space for the other constructions are subtracted from that. However, for orientation reason, it was deemed better to include the building in the PDF, be it in a transparent way, to show the difference with the other parts.

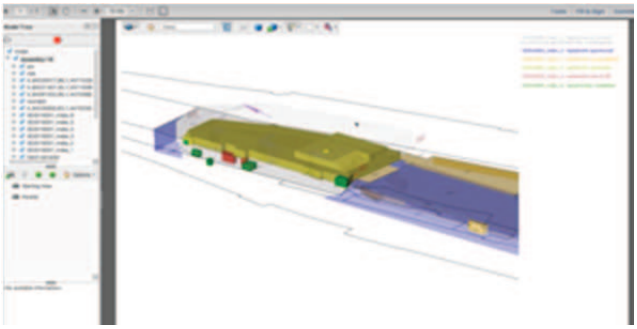

Figure 4. 3D PDF, official document that visualises rights of multi-level ownership in 3D. It concerns the combined city hall and railway station in Delft. The interactive 3D visualisation can be viewed here: https://www.youtube.com/embed/vFMoH-2r7xo

In the third step, the 3D representations of the rights were translated into PDF and included in a deed, supplementary to the deed in which the rights were established (in step 1). The purpose of the deed was to specify the objects of the registered rights. This deed was also

recorded in the Land Register as on official deed, see Figure 4. The 3D deed can be downloaded from Kadaster (2016).

The deed contains a 3D representation of the rights; a legend of the rights, coordinates of the national reference system that show the location of the complex in the real world. In addition, since the real rights are still secured via 2D parcels, the 2D cadastral map in which the parcels of concern are identified, is part of the 3D deed.

Also the 3D data itself (describing the 3D geometries of the legal volumes) were registered in view of future needs to adjust the juridical situation (not as part of the public registers).

In the cadastral registration a 3D complex ID was generated and the different rights have been assigned unique indices. These IDs are both registered in the drawing as in the textual part of the deed. Also a reference was made in the cadastral registration to the interactive, 3D visualisation of ownerships in 3D.

The multi-level ownership can be queried in 3D via the cadastral registration: The registration shows a parcel complex on which a notification of a "3D visualisation" is established. This notification refers to the deed with the 3D drawing. This 3D PDF is publicly available and can be viewed in any PDF viewer that supports 3D. In the viewer, the 3D situation can be interactively viewed, one can see the relationship between the different legal volumes (which cannot be done if they are registered via separate 3D surveys) and one can make the individual volumes visible (or invisible) for further inspection. When "clicking" on objects, one sees the 3D-indices and owners of the volumes.

4. EVALUATION

As mentioned before, to avoid lengthy discussions between experts from different disciplines, the solution was sought within existing legal and cadastral frameworks with the aim the further develop the solution after evaluation of this first 3D cadastral case. This section evaluates the registration case for future developments.

4.1 Advantages of a 3D cadastral registration

It is clear that a 3D approach can better represent complex ownership situations.
An example is a revolving door of the municipality that extends into the property of NS but that does not extend to the ceiling (see Figure 5). Therefore, the question arises: to whom does the space belong from the top of the door to the ceiling?

Another example that 2D cannot sufficiently represent the ownership in complex situations, was that the conversions of the 3D data about the physical construction into legal volumes revealed that some additional parcels should be entitled with limited rights which had been ignored in the initial registration.

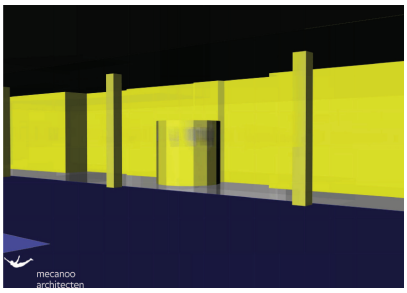

Figure 5 Revolving door of municipality of Delft extending in property of another party

Another advantage of 3D above 2D, is that the registration is more cost effective.
First because the cumbersome process of describing the complex situation in a 2D description required for the registration can be skipped, if it can be done at all, as showed above (and vice versa 3D reconstruction from a poor registration required for future transactions)is not needed). But also costs of surveying can be saved because surveying within complexes is no longer necessary to assure that the 2D parcel map reflects the 3D situation. These costs may be significant in cases of multi-level ownership where boundaries are not exactly on top of each other when projected on a 2D plane.

In conclusion, a 3D cadastral registration of multi-level ownership has many advantages. However, the fact that that the 2D cadastre map does no longer reflects the legal situation requires a change in the cadastral legislation and procedures (see next section).

4.2 Lessons learned

Several observations will help to improve the 3D registration in the future, these are:

4.2.1 3D drawing to support the complete registration chain

First, the advantages of a 3D drawing can only be used in all its potentials if the 3D drawing is part of the registration process from the start.

In this case it was decided to first register the property rights in a "traditional" way, to secure the rights before the construction of the building was completed. The consequence was that the legal reality was first made "flat" (described by lawyers in 2D) and then had to be reconstructed again in 3D from the existing documents. As could have been expected, this resulted into grey areas without an explicit ownership in the deed, as was explained above for the space the revolving door. A 3D approach from the start would have avoided these grey areas. But more importantly it would have significantly saved time in the process (a foreseen advantage of 3D above 2D), because 3D reconstruction of complex situations from 2D descriptions would not have been needed.

4.2.2 Reconsidering the "specialisation principle"

Another lesson learned is related to the so-called "specialisation principle" followed by Dutch land administration (which is also applicable in many another countries). Because of this principle, the building complex of this study still needed to be divided into 15 cadastral parcels. The initial idea of this specific complex was also to not divide the ground parcel. However, for historical reasons this division of parcels is indeed the way to satisfy the

specialisation principle. It appeared that significant time was needed into researching the ownership situation of these small parcels (specifically at those locations where the tunnel crosses small objects above ground).

Current techniques show that there are better ways to provide insight in multi-level ownership than dividing parcels into smaller parcels. Therefore, it is indeed recommended to register only one parcel in such cases on which the 3D visualisation of the 3D ownership rights of the whole complex is registered. This requires a change of the *Kadasterbesluit* (Cadastre Decree) stating that surveying within a building complex is not needed, if all rights within the complex are represented in 3D. As argued before, this will also save costs.

4.2.3 3D parcels

The legal volumes formed with real rights and that can overlap with several ground parcels, can be considered as 3D parcels according to the definition of (Oosterom et al, 2011):

> *"A 3D parcel is defined as the spatial unit against which (one or more) unique and homogeneous rights (e.g. ownership right or land use right), responsibilities or restrictions (RRRs) are associated to the whole entity. Homogeneous means that the same combination of rights equally apply within the whole 3D spatial unit. Unique means that this is the largest spatial unit for which this is true. Making the unit any larger would result in the combination of rights not being homogenous. Making the unit smaller would result in at least two neighbouring 3D parcels with the same combinations of rights."*

The legal volumes meet this condition and are registered with an own ID.

4.2.4 Legal boundaries versus physical boundaries

Another lesson learned, is that juridical boundaries in 3D are not always bound by physical boundaries. For example, we had to agree on how to demarcate the ownership of the space that accommodates the (use of a) staircase. Only the visualisation of a constructed building is clearly not enough. The division between the different rights needs to be unambiguously clear to assure legal certainty.

4.2.5 Registration of the 3D data

There is also a lesson to learn from the registration of the 3D data needed for validation and updating in the future. The case has six legal rights, and each of them can have multiple volumes. The legal volumes for one of the rights can be seen in Figure 6a; there are in total seven of them and they refer to the green ones in Figure 4. Observe that these are rather simple volumes, but that some are more complex, such as the one on the right in Figure 6b (which is the green volume in Figure 4). The legal rights have been drawn originally in a specialised CAD software (Rhino 3D) and exported to a 3D PDF for everyone to inspect and visualise. In this specialised software, we first ensured that the volumes were closed (i.e. 'watertight') and that they were valid. This could be done with functions available in the software.

However, since our ultimate aim is to register these rights and allow everyone to manipulate the geometries, the attempt was to store them in a format that is open and easily readable. Several challenges were faced in doing so. First, the export function of the software was

modifying the volumes, by adding several vertices on surfaces and on edges (presumably to translate parameterised geometries of the CAD software into explicit geometries), as shown in Figure 6 on the left. While in theory these should not be an issue, the software inserted these *very* close to each other at certain locations (at the sub-millimetre level), which can be problematic when imported in different software. Second, the definition of what is a valid volume is different in different software and in different disciplines, as Ledoux (2013) explains. In a GIS context, the ISO19107 standard defines a solid (a 3D volumetric primitive) as closed volume, and there should for instance not be any self-intersections in the bounding surfaces and no duplicated vertices. Unfortunately, in CAD software, self-intersections are sometimes allowed. This means that when we validated the volumes against the ISO19107 rules, some of the volumes were invalid. The solution to this problem is to decompose the volumes into sub-parts, for example if GML (Geographic Markup Language) was used, then `CompositeSolid` would be used. It is part of the future work to define a workflow so that practitioners can export their legal rights and store them in valid GML.

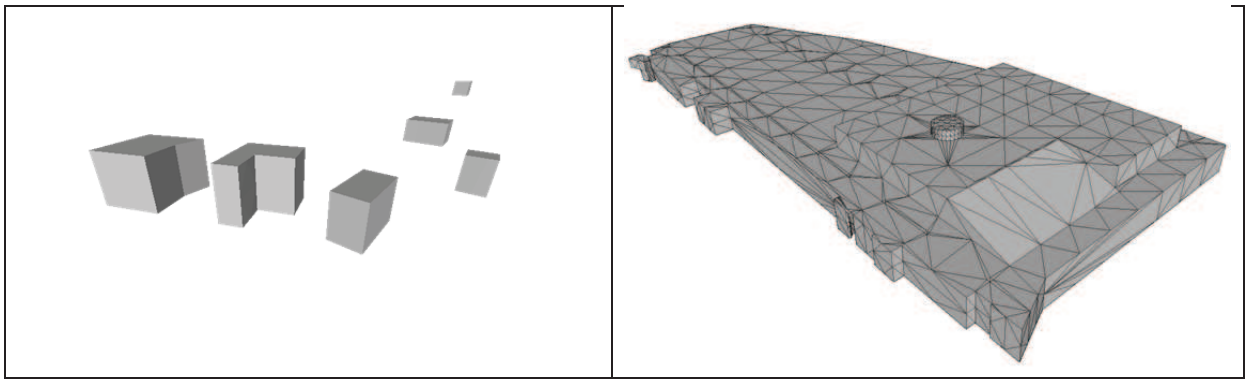

Figure 6. Examples of legal volumes. (a) 7 different volumes ofone right; (b) one complex volumes that has been triangulated

4.3 Questions for further research

Based on experiences from the first phase, investigations are currently underway how to establish a more formal procedure for 3D registration of multi-level ownerships. In this investigation issues need to be addressed such as:

- Can the "Kadaster" enforce such a 3D registration in certain situations and if so, in which cases?
- What is required if 3D needs to be part of the registration from the start? Can potential stakeholders be provided with a workflow that explains all steps required from legal volume construction to PDF including export from legal volumes constructed in CAD software to valid GML?
- How to change the legal rule so that one parcel can be registered for one multi-level ownership situation instead of dividing the 2D parcels so that they reflect constructions above and below the surface?
- What is the legal status of the drawing? Additional to deed (3D is leading) or for clarification of 2D deed only (2D is leading). If the 3D deed is leading, then the 3D data need to be validated via an official procedure. How to implement these procedures?
- What are the (minimum) requirements for the 3D drawing?
- What to do if there is a difference between the deed and the 3D visualisation?

- What is the relationship between 2D and 3D (should the 3D visualisation always fit within 2D registration)?
- What is that status of the 3D legal volumes? Can they be treated as single 3D parcels, i.e. as individual objects?
- How to maintain the underlying 3D data?

5. CONCLUSION

In this paper we presented the first 3D cadastral registration of multi-level ownership in The Netherlands.

Although it is possible to legally establish 3D rights since 200 years, until recently it was impossible to visualise these 3D rights.

Since on the one hand technologies to handle 3D information have matured and on the other hand multi-level ownership situations are encountered that cannot be unambiguously registered in the current 2D based system, the Kadaster is developing a solution to improve the registration in multi-level ownership situations.

Based on the experiences of the 3D registration presented in this paper, the 3D registration will be further developed and regulations will be adjusted accordingly.

ACKNOWLEDGEMENTS

We thank all partners of the 3D cadastre study case for their contributions. These are:
- The legal entities of the 3D cadastre case: ProRail/Railinfratrust, NS Vastgoed and the Municipality of Delft.
- The architect bureau Mecanoo who designed the station and converted the design into geometries representing legal volumes.
- Houthoff Buruma civil notaries that have issued the certificate for the deposit in the Land Registry.

This research is supported by the Dutch Technology Foundation STW, which is part of the Netherlands Organization for Scientific Research (NWO), and which is partly funded by the Ministry of Economic Affairs (Project code: 11300).

REFERENCES

Atazadeh, B., M. Kalantari, A. Rajabifard, S. Ho and T. Ngo (2016). Building Information Modelling for High-rise Land Administration, Transactions in GIS, doi: 10.1111/tgis.12199.

El-mekawy, M., Paasch, J. and Paulsson, J. (2014). Integration of 3D Cadastre, 3D Property Formation and BIM in Sweden, 3D Cadastre workshop 2014, Dubai.

Kadaster (2016). 3D deed, can be downloaded from:
http://www.kadaster.nl/web/artikel/download/Nieuw-Downloadpagina-24.htm

Karki, S. and R. Thompson (2014). Position paper on "Initial registration of 3D parcels", 3D Cadastre workshop 2014, Dubai,
http://www.gdmc.nl/3DCadastres/workshop2014/programme/Workshop2014_29.pdf

Ledoux, H. (2013). On the validation of solids represented with the international standards for geographic information. *Computer-Aided Civil and Infrastructure Engineering* 28 (9), 2013, pp. 693–706.

Olivares García, J.M., Virgós Soriano, and Amalia Velasco Martín-Varés, A. (2011).
3D Modeling and Representation of the Spanish Cadastral Cartography, 2nd International Workshop on 3D Cadastres 16-18 November 2011, Delft, the Netherlands

Stoter, J., Ploeger, H.D. and P. van Oosterom, 2013. 3D cadastre in the Netherlands: developments and international applicability. Computers, Environment and Urban Systems 36, 2013

van Oosterom, P.J.M. van, Stoter, J.E., Ploeger, H.D., Thompson, R. and Karki, S. (2011). World-wide inventory of the status of 3D Cadastres in 2010 and expectations for 2014. In G. Schennach (Ed.), Cadastre 2.0 (pp. 117-122).

BIOGRAPHICAL NOTES

Jantien Stoter is full professor 3D Geoinformation, at the Faculty of Architecture and The Built Environment. She obtained my PhD degree (3D Cadastre) in 2004. She combines her professorship with jobs as researcher at both the Kadaster and Geonovum. She chairs the EuroSDR Commission "Data Modelling and Processing" and is leader of the national 3D SIG (Special Interest Group) as well as of the EuroSDR 3D SIG. Since March 2015, she is vice-chair of the OGC 3D Information Management Domain Working Group (OGC 3DIM DWG). Her research interests are 3D, automated generalization and information modelling. For her research on 5D data modelling she received the prestigious Vidi award of the Netherlands Scientific Foundation (NWO). In addition, she received a personal grant from the European Research Council (ERC) for her proposal Urban Modelling in higher dimensions.

Hendrik Ploeger is professor at the Faculty of Law, VU University Amsterdam and associate professor at the Faculty of Architecture and the Built Environment, Delft University of Technology and member of the Geoinformation Governance Knowledge Centre. His field of expertise is land law and land registration. From 2001 onwards one of his main research areas is the legal aspects of multiple use of land and the 3D and 4D registration of rights and restrictions.

Bernardus Hendrikus Johannes (Ruben) Roes is chief registrar of the Dutch Land Register and Cadastre since February 1st 2016. The main topics of his work contain public law restrictions, the development of a 3D registration and the renewal of the registration system. He is also a teacher at the Dutch Grotius Academy (Nijmegen) in the postdoctoral education programme (Real Estate Law) for lawyers and notaries.

Els van der Riet is manager legal affairs at the Delft Railway Zone ("Spoorzone Delft") project for the municipality of Delft. She holds a Masters degree in Law from the VU University Amsterdam (1984) and a Masters in Comparative Law of the University of Illinois (U.S.A.) (Fulbright scolar, 1985). She worked as an Dutch attorney-at-law in private practice, mainly in real estate, before coming to Delft, including as a foreign lawyer in Tokyo, Japan (gaikokuho-jimu-bengoshi, 1994-2001). During this period, she also was an associate professor at Temple University (Tokyo campus, 2000) for Introduction to European Law.

Filip Biljecki is a PhD candidate at the 3D Geoinformation Research Group at the TU Delft. He holds a BSc in Geodesy from the University of Zagreb, and an MSc in Geomatics from the TU Delft. Filip's research interests are 3D city modelling, CityGML, and spatial data quality.

Hugo Ledoux is an assistant-professor in 3D geographical information systems (GIS) at the Delft University of Technology in the Netherlands. He holds a PhD in computer science from the University of Glamorgan (Cardiff, UK) and a BSc in geomatics engineering from the Université Laval (Québec City, Canada). For his research, he is particularly interested in combining the fields of GIS and computational geometry. His work involves developing topological data structures to store these tessellations, and designing algorithms to analyse and extract information from the datasets. He strongly believes in implementing his research ideas. He is currently working on the validation and the automatic repair of polygons and

polyhedra as found in GIS, the higher-dimensional modelling of geographical information (ie 4D+), and the smart simplification of LiDAR datasets.

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