The Phased 3D Cadastre Implementation in the Netherlands

Jantien STOTER, Peter VAN OOSTEROM and Hendrik PLOEGER, The Netherlands

Key words: 3D Cadastre, Cadastral Modelling, Prototype, 3D Cadastre implementation

SUMMARY

After more than a decade of 3D cadastre research in the Netherlands, including detailed analysis of various complex 3D right configurations and development of several prototypes, the Dutch Kadaster is implementing a 3D cadastre solution.

Earlier research showed that the registration and publication of rights on multi-level property is possible within the existing system in the Netherlands. However, as demonstrated in these earlier publications, this way of registration has limitations. The most important is that it may require a mental exercise to understand 3D property situations based on information available in the land and cadastral registers. Sometimes the registration is ambiguous and reality is even needed to understand the registration instead of vice versa. To meet these limitations, the Dutch Kadaster is currently designing and implementing the cadastral system extension for registration of 3D rights (and restrictions).

The solution is partly driven by the alternatives as studied in previous research and partly by the observation that implementing 3D cadastre in practice is a process that requires experience- and knowledge- building. Uncertainties on the implementation of a 3D cadastre in a specific country exist due to technological developments on the one hand and cadastral and legal developments on the other hand. Also two disciplines are involved (i.e. technical and legal experts) who need to understand the impact of 3D cadastre in each other's domain for proper 3D cadastre developments. To meet these uncertainties, the proposed 3D cadastre NL solution consists of a two-phase process. The aim of the first phase is to gain experiences by introducing evolving technologies in the legal domain of 3D cadastre. The second phase will aim at a more advanced 3D cadastre solution, which will accomplish a 3D cadastral registration at a fundamental level. Both phases do fit in the ISO FDIS 19152 Land Administration Domain Model via 3D country profiles for the Netherlands.

This paper will start with identifying the situations appropriate for a 3D approach. After that the two phases are further explained. The paper will end with conclusions and work in progress.

The Phased 3D Cadastre Implementation in the Netherlands

Jantien STOTER, Peter VAN OOSTEROM and Hendrik PLOEGER, The Netherlands

1. INTRODUCTION

Cadastral registration of multi-level property increasingly receives attention because more and more situations occur for which common 2D registration appears to be problematic. Although most legal systems provide the possibility to create 3D property rights, i.e. property rights that represent a volume that is delimited in length, width, height and depth (Paulsson 2007; Ekbäk 2011; Liat Choon and Hussin 2012), the main registration entity is mostly still a 2D parcel. In the Netherlands, as in many other countries, 3D property rights are projected on the plane. In the case only a part of one (or more) 2D parcel(s) is affected, the ground parcel(s) will be subdivided based on those projections. From a legal perspective the current way of registration correctly represents the situation. Still the registration itself may be unclear because many small parcels may be necessary to register one single object. This is illustrated in Figure 1 where a building, appropriately named "The Bridge", is constructed over several other buildings and a public road. The ownership right for the building has been established by a right of superficies ('building lease') on all intersecting surface parcels. To better localise the areas to which these rights apply, specific parcels were generated by the projection of the building, which resulted in a fragmented parcel pattern. Another example of parcel fragmentation as a result of the registration of two 3D property rights on the same piece of land is described in Section 2.

The consequence of this way of registration is that the registration is ambiguous and that knowledge of the factual situation might be necessary to understand the registration instead of vice versa. In addition, the registration of the right on a single real world object over several parcels introduces a risk for errors in maintaining the cadastral registers.

Several studies on national and international 3D cadastral developments have been carried out (Onsrud, 2003; Benhamu and Doytsher, 2003; Stoter and Salzmann, 2003; Stoter and Ploeger, 2003; Stoter and Van Oosterom, 2005, 2006; Paulsson, 2007; Döner, et al., 2010; Karki et al., 2010; Eriksson and Jansson, 2010; Pouliot et al., 2010; Aien et al., 2011; Rahman et al., 2011; Guo et al., 2011). These studies performed detailed analysis of various complex 3D right configurations and developed several prototypes. Until now these studies focused on studying the optimal legal, technical and cadastral frameworks for 3D Cadastre and they proposed several (theoretical) alternatives for proper cadastral registration of multi-level property. However, as concluded in Van Oosterom et al. (2011) hardly any cadastral registration made the step towards a fundamental solution for 3D cadastre. Instead 3D parcels in cadastral maps are (mostly) limited to apartment units, although various countries are investigating moving towards 3D registration. An example is the Russian Federation (Vandysheva et al., 2011).

(photo by Frans Schouwenburg, Creative Commons-licence).

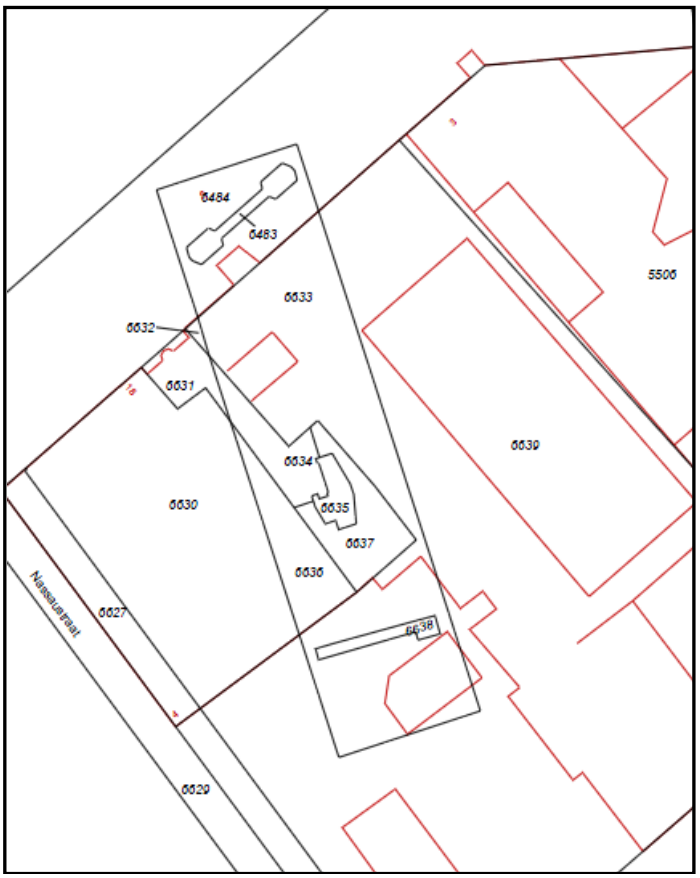

Figure 1. The Bridge (‘*De Brug*’) building in Rotterdam above other buildings and roads with the cadastral map of this situation.

The limited advances in full 3D cadastre implementations throughout the world might be explained by the fact that the implementation of a 3D cadastre requires close collaboration between legal and technical experts in an empirical environment to understand the impact of each other’s domain. Therefore this paper presents the developments in the Netherlands where achieved research results on 3D cadastre are brought into practice. Also in an international perspective this is an important step forward.
The proposed solution consists of a two-phase process. The first phase fits within the current national cadastral and legal frameworks. The aim of the first phase is to gain experiences and to acquire knowledge by introducing evolving technologies in the legal domain of 3D cadastre. The second phase will build on these experiences and will implement a future-oriented and sustainable solution, also implementing new technologies and allowing a more fundamental change. Both phases fit in the ISO FDIS 19152 Land Administration Domain Model (LADM; Lemmen et al., 2010; ISO/TC211, 2012) with the two corresponding LADM 3D country profiles for the Netherlands.

The paper is organised as follows. Section 2 first identifies the situations appropriate for a 3D approach. This is important for achieving common understanding of multi-level property situations that should be considered for 3D registration. Section 3 proposes the two phases of implementation of 3D cadastre and presents first results. The paper ends with conclusions.

2. SITUATIONS APPROPRIATE FOR 3D REGISTRATION

Our research identified the following three situations in which the spatial dimensions are relevant to be considered for 3D registration:
1)Multi-level property resulting from a building that is partly constructed on or in another's land. Based on the rule of "horizontal accession to real estate", the result of the construction over the parcels boundary is horizontal division of ownership. For the cadastral registration these situations are only relevant when a right has been registered that gives the right to have this part of the building above or under another property, i.e. right of superficies (as in Figure 1) or easement.
2)Complex, multi-level use rights registered with a right of superficies, long lease or easement that cannot be sufficiently represented in the 2D cadastral registration. The assurance of the legal status of these situations requires more 'visual' registration than is currently practised. The use rights could have been established either for physical constructions, utility networks or 'air parcels' (e.g. easements for ensuring free wind). Specific attention is paid for the "rights-in-right" situation, for example when the right of superficies is subdivided in space by using easements.
3)Property rights in apartment complexes that require further specification in 3D: such as apartment units spread over several floors (e.g. apartment unit with the main part on the second floor, with an individual parking spot in the garage in the basement) and/or apartment units that do not have the same 2D geometries for all floors and/or large building complexes. We distinguish apartment units as separate category, since they always handle about physical constructions and regulations for obliged drawings are already in force. In LADM terminology (ISO/TC211, 2012), an apartment complex would correspond to a single LA_BAUnit consisting of multiple LA_ Spatial Units.

An example of a complex, multi-level property situation (type 2) is the creation of two 3D property rights for a building (an office tower) on one hand and the underground parking under it on the other hand. The example given is located at the South-axis business district of Amsterdam (Figure 2). The foundation piles of the office tower are situated in the underground parking. For both constructions long leaseholds have been established by the land owner, the municipality of Amsterdam. As land owner the municipality retains all rights on the public space on the roof of the parking that is not occupied by the office tower; as near the entrance of the building (shown in Figure 2).

Figure 2. Photograph of the real situation of case of type 2 (building on the right side)

The lease right on the office tower on top of the parking is registered through its foundation piles resulting in about 80 mini-parcels in Figure 3. Actually the foundation piles of the office tower run through the underground parking itself (from the roof to the floor of the parking). Therefore the 3D property rights created here are of a rather complex nature, i.e. the footprint of the foundation piles are used and not the footprint of the building (the building stands on the ground).

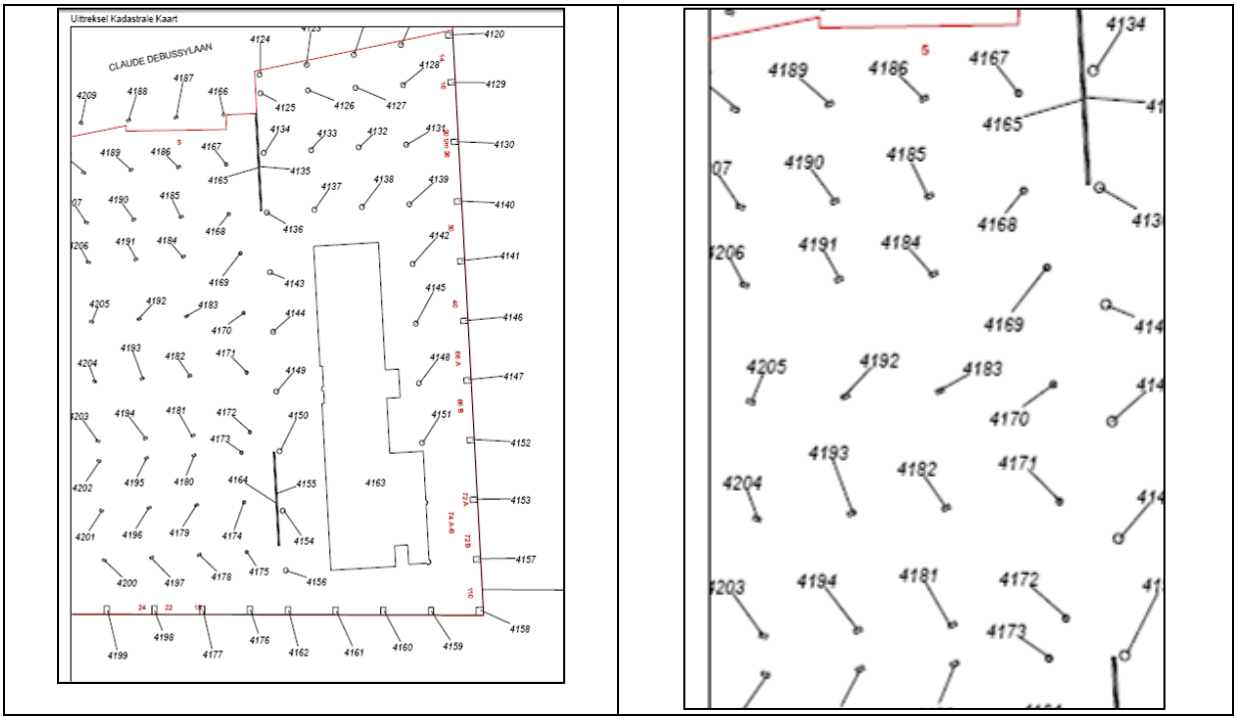

Figure 3: Cadastral map showing the mini-parcels established for the foundation piles of the building in Figure 2

Consequently-as the authors experienced themselves-the actual dimensions of the 3D property rights can only be understood properly after visiting the site itself. The registration is even made more complicated since the office tower is divided into apartment units (therefore creating the situation that each apartment owner holds a share in the leasehold). The mini parcels together form the "mother" parcel of the whole apartment complex.

Apart from the resulting non-transparent property registration, this "footprint" way of registration leads to inefficient parcel creation, which are hard to maintain. The obscurity of those mini-parcels is even bigger in case of rights for two distinct objects above and below the parcel, such as a building-over-road combined with underground constructions. It may well happen that in a deed referring to the mini-parcels a typing error is made or that in the future one of the parcels is forgotten in a deed transferring the 3D property right. Another disadvantage of these mini-parcels is that after subdivision of the original larger parcel all the rights, limitations and restrictions of the original parcel are copied to all the mini-parcels, while most likely those do not apply to all the mini-parcels. In most situations not the initial

creation will cause problems, but the maintenance afterwards: updating the same legal fact attached to 80 mini-parcels after one real world change might be quite error prone.

3. PHASED 3D CADASTRE IMPLEMENTATION

The main conclusion from previous case studies in the Netherlands (Stoter and Salzmann, 2003; Stoter and Ploeger, 2003; Stoter and Van Oosterom, 2005, 2006), and also shown by the case presented in the previous section, is that the registration and publication of 3D property rights is possible within the existing system of land registration in the Netherlands. However, the way it is currently done may require a mental exercise to understand the situation based on information available in the land and cadastral registers.

Apart from a better legal security in case of multi-level properties, the implementation of a 3D cadastre will also save costs. The measurement of each mini-parcel in the field, in situations as shown in the case in the previous section, costs 1000 euros per parcel. Consequently the registration of the leasehold for the building through 80 mini-parcels cost 80,000 euros. This money can be saved when the building is registered through one 3D legal volume.
In this section we propose the Netherlands solution for 3D cadastre implementation. This solution is partly driven by the alternatives as studied in previous and partly by the observation that implementing 3D cadastre in practice is a process that requires experience- and knowledge-building. Uncertainties on the implementation of a 3D cadastre in a specific country exist due to technological developments on the one hand and cadastral and legal developments on the other hand. Also two disciplines are involved (i.e. technical and legal experts) who need to understand the impact of 3D cadastre in each other's domain for proper 3D cadastre developments. To meet these uncertainties, the proposed 3D cadastre NL solution consists of a two-phase process. The aim of the first phase (Section 3.1) is to gain experiences by introducing evolving technologies in the legal domain of 3D cadastre. The second phase (Section 3.2) aims at a more advanced 3D cadastre solution, which will accomplish a 3D cadastral registration at a fundamental level.

3.1 First phase of 3D cadastre implementation

The first phase of 3D cadastre implementation exploits one of the LADM conceptual modelling options for 3D situations; i.e. separate level with spatial units, which are associated with 3D drawing (LA_SpatialSource, playing the role of a sketch). The solution fits within current cadastral and legal frameworks and can therefore be implemented within a short time frame. In addition, the implementation will provide an empirical environment to gain experiences and support by all the stakeholders involved.

The implementation works as follows. In case of 3D property rights, it is no longer allowed to subdivide a 2D parcel by means of the projection of 3D objects in the cadastral map because this results in an unclear registration. Instead the original parcel will be maintained as cadastral object and for additional 3D cadastral objects a registrar requires a detailed 3D representation that provides insight into the property situations (established with either apartment right, right of long lease, right of easement or right of superficies). Such a 3D representation can be registered via a 3D drawing (in pdf format) within the ELAN system

(Kadaster, 2007). A 3D pdf (Adobe, 2012) provides interaction and query possibilities that are very helpful in understanding 3D situations.

Because the first phase-solution is based on current regulations, the registration of a 3D pdf is not obligatory in a strict formal sense, but in practice a registrar can request the registration of a 3D pdf for sake of clearness, to avoid the fragmented parcel pattern that is caused by projecting 3D objects on the cadastral map. This registration is formulated in a guideline that supports public notaries (responsible for drafting the deed needed for the registration of property of real estate in the Netherlands) in deciding in which situations this 3D registration approach is preferred (Section 2) and how they can accomplish a 3D registration, i.e. what information should they provide, in what form and in what way this information can be generated. Also the parties will be encouraged to declare the 3D representation as legally binding. This is needed (and beneficial for all parties), because the current legal and cadastral frameworks do not yet accept 3D data nor exact demarcation of legal spaces other than apartment units.

A notification is administrated on the parcel(s) on which a 3D representation is registered. The 2D projection of the 3D representation will be added for reference to the cadastral map by an extra graphics layer, like is done in Australia (Queensland Government, 2008; Stoter and Van Oosterom, 2005) and Norway (Valstad, 2010). The content of this additional graphics layer is shown on the cadastral map with symbology different from 'normal parcel' (boundaries) and buildings (as traditionally depicted on the Dutch cadastral map for reference purpose). Therefore the existence and impact of the 3D legal space on the cadastral parcels becomes visible.

Although current frameworks are used, the proposed 3D registration makes new use of those possibilities and therefore it is an innovation for cadastral registration in the Netherlands. In fact the major breakthrough is that the option to register a digital 3D drawing (possibly legally binding) will actually be practised. In addition, because the 3D drawing provides insight into the spatial dimensions of the right, new 2D parcels do not need to be created to delineate the exact boundaries of the 3D property on the ground parcel and creation of fragmented parcels can be avoided.

The (minimum) information required in the 3D representation to understand the property situation are identified as follows:

- 2D ground parcels that overlap (in projection) with the 3D legal volumes, draped over a Digital Terrain Model (to localise the parcels in space; e.g. is the legal space located above or below the earth surface). The overlap of the 3D space with the ground parcels should be identified (e.g. by hatching the specific area of the ground parcel).
- 3D (graphical) description of legal space.
- To be in sync with the guidelines for drawings required for apartment units, the legally required 2D cross sections with accompanying annotations (e.g. unique identifier, north arrow etc). These cross-sections can be just another view on the same data, as will be shown in Figure 4.
- Objects needed for reference and orientation in the 3D environment, i.e. at least the same as in current 2D cadastral map, which is 3D topography for reference purposes. The

source for this could be the 3D topographic database, currently under construction at the Kadaster (Oude Elberink et al, 2012).
- The 3D drawing should localise the 3D legal volume in both a local coordinate system and the national height datum system.

Within the current framework no 3D data can be submitted for registration (in contrast to 3D graphics drawings, which can be submitted for registration). Therefore as long as the 3D space can be well visualised in 3D, the representation is accepted (i.e. it is not possible to validate the data nor will the Kadaster check the data in the field). One should keep in mind that the reference to physical markers prevails above the coordinates in the cadastral map in the system of the Netherlands. Therefore also in 3D the main aim of the drawings is to sufficiently explain the intention of the involved parties.

Initial results

It is important that the 3D registration does not bring a lot of extra costs. Therefore we investigated in collaboration with a design and construction company (*VDNDP Bouwingenieurs*), how the 3D drawings can be generated from existing digital design drawings (CAD) of the constructions. These types of companies are also the ones who currently prepare the map of divisions for apartment complexes.

Figure 4 is the result of the foreseen workflow to generate 3D property drawings for an apartment complex. It shows several (cadastre-relevant) views (also cross-sections) on the same source data that was generated to construct the building.

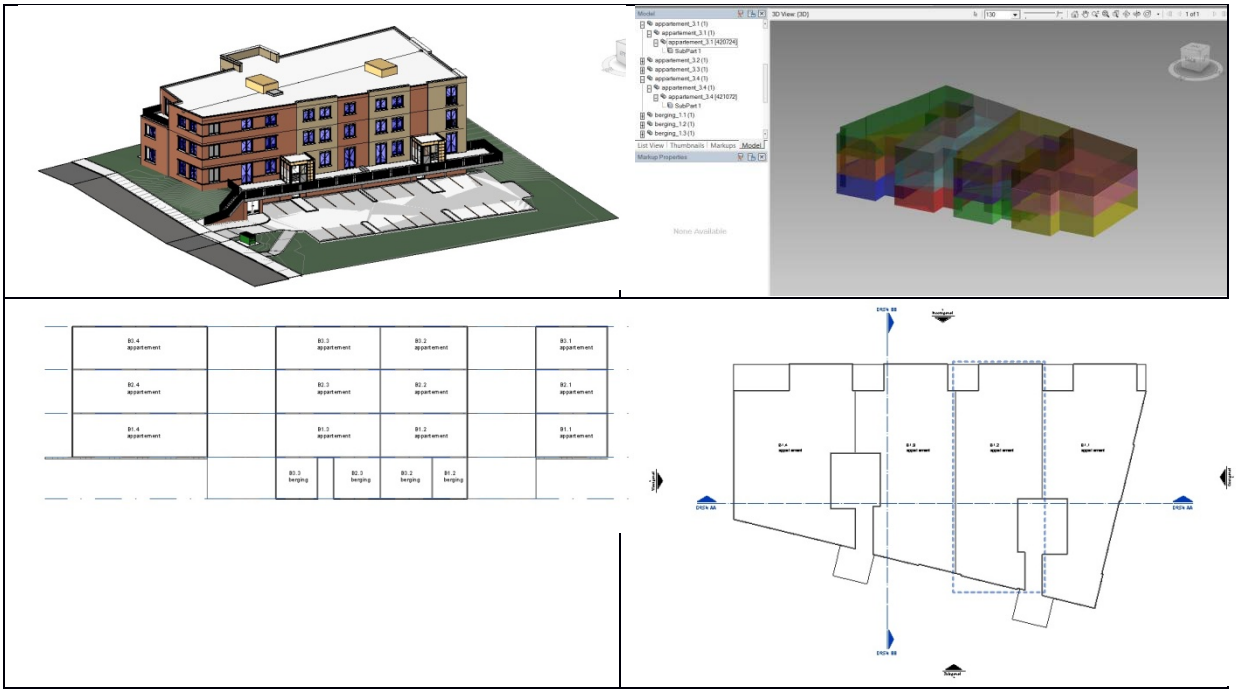

Figure 4. Registration of 3D representation of 3D property rights via different views on the same 3D design drawings; top left: artistic impression, top right: respective view 3D legal spaces, bottom left: vertical cross section, bottom right: floor plan of 1st floor

From our experiences we can conclude that the costs to generate the 3D cadastre information in this format are similar to the costs involved for generating the currently obliged 2D maps of divisions (in case of apartment units).

The outcomes of this hand-on study have been converted in a best practice procedure to support external parties to generate the information recommended for a 3D registration.
It should be noted that the described workflow focuses on newly built construction for which digital drawings are at hand.

3.2 The second phase: 3D registration for the long-term

The disadvantage of the first phase-solution is that it focuses on visualisation. Therefore the 3D data is not available as such in the registration, which has several drawbacks. The data is necessary to check the validity of the 3D representation; e.g. is the space to which the right applies closed? Does it not overlap with spaces of other rights? In addition, if future transfers need to alter the 3D drawings, they cannot make use of the previous version of the data and they might need to collect the data again with risks of inconsistencies. Finally, data (and not just isolated 3D graphical illustrations) are needed to generate an overview that combines different 3D representations in a 3D overview; i.e. a true 3D cadastral map.

Techniques for 3D data acquisition, management and distribution are in reach. The next step is to optimally exploit these techniques to meet the more advanced implementation of a 3D cadastre. Therefore the planned solution of the second phase implements a full 3D cadastre alternative, i.e. combination of traditional, infinite parcel columns and volume parcels, defined by 3D data (e.g. polyhedrons) and not limited by 3D drawings.

The implementation requires a 3D geometrical representation in all cases identified as multi-level property situations (see Section 2). In this representation, the location information has a more formal meaning than in the first phase.

In first instance, the Kadaster will not check the data and can therefore not guarantee that the 3D representation correctly reflects the real situation: this is still left to the parties. This fits the current Dutch system of land registration based on a registration of deeds, in which the land registers and cadastre do not provide any guarantees as such for third parties (also not in 2D). It is also similar to the way utility networks are currently registered as real estate objects by the Dutch Kadaster (Döner, et al., 2011).

How the Kadaster will accept the 3D data itself (which format) needs to be decided: (City)GML (OGC, 2012), or IFC (i.e. Industry Foundation Class; IFC, 2012) from the Building Information Model domain or …? In a future step Kadaster can decide to be responsible that the data correctly reflects the real situation like in a ‘positive’ system of title registration, as in Queensland (Queensland, 2008). In that case, the Kadaster should check the data on geometrical and topological correctness as well as on eventually overlap with other legal volumes. This is not trivial; see Thompson and van Oosterom (2011). However such an option needs a fundamental shift in the current principles of land registration of the Netherlands.

The following principles further explain the implementation:

- The legal space is still related to one or more ground parcels (although one right of superficies can apply to several legal volumes within one parcel). The introduction of the possibility of free lying legal spaces would require a change in the Civil Code, which would take years. Therefore, when a 3D property does overlap with several ground parcels, for every ground parcel a specific right needs to be established. However this can be established in a single deed with one drawing, involving multiple surface parcels and a single volume corresponding to the 3D object. This volume gets an own identification. This is the only way to treat one real world object as a whole, even if it goes through several ground parcels.
- The list of situations that legally require a 3D registration will be defined in consultation with the notaries and be based on the experiences gained from applying the (voluntary) short-term solution (first phase). In addition to building complexes, this will also include utility networks, often spanning multiple surface parcels.
- Apart from the format, also the allowed geometries need to be decided, i.e. fully enclosed by flat surfaces (polyhedron) or even by curved surfaces with precise mathematical descriptions of such parts (e.g. cylindrical or spherical surface patches)? And is it allowed to have 3D representations that are open at the top (sky) or at the bottom (earth)?
- The required precision relates to the value of the measures, i.e. also in 2D the reference to physical markers currently prevail above the boundaries in the cadastral map. However, having exact 3D information available as conversion of exact 3D drawings (or measured in the field by advanced tools) may question this rule in the Netherlands and opt for a different approach. To add measures to constructions, it is preferable to follow the national standard on measuring volumes and areas within constructions (NEN 2580, 2007). This standard is used in the building and construction domain.

The optimal implementation will be further shaped, also by experiences gained during the first phase and an analysis of on-going developments in other countries (Queensland Government, 2008; Valstad, 2010; Olivares García et al., 2011; Vandysheva et al., 2011).

4. CONCLUSIONS

This paper presents the 3D cadastre developments in the Netherlands and proposes an actual implementation of a 3D registration of 3D property rights fitting within the international standards of the ISO 191xx family (and more specifically ISO FDIS 19152, Land Administration Domain Model; LADM).

The proposed solution builds on alternatives proposed in earlier research and consists of two phases. The first phase (for the short term) fits within the current cadastral and legal frameworks and the second phase focuses on a long-term solution that also facilitates to register 3D geometrical data apart from a 3D drawing. Both phases target an appropriate registration of 3D rights and restrictions. Making this 3D information accessible via a (direct) link in the cadastral map is part of the solution (phase one). However the registration of 3D data is under study for phase two.

This paper proposes a solution for 3D registration within a given legislation and therefore a national setting. However the need to develop the current land registration system towards an

efficient and clear representation of complex property situations that occur as a result of intensified land use and multiple use of space is certainly not limited to the Netherlands. Other countries face similar limitations of legislation and/or cadastral regulations to facilitate appropriate 3D registrations, as can be concluded from the international comparison carried out by the FIG joint commission 3 and 7 working group on 3D-Cadastres (van Oosterom et al., 2011). As the presented solution is based on international standards, similar approaches can be applied in other countries; e.g. as illustrated with the 3D cadastre prototype in the Russian Federation (Vandysheva et al., 2011).

The developments in the Netherlands as described in this paper will therefore contribute to further study and subsequent development in other countries. However it does not provide a "manual" for implementation that can be followed anywhere in the world. The actual implementation of a 3D registration will always depend on the characteristics of the current land law and system of land registration in a certain jurisdiction.

Future work will refine the goals for the second phase of the implementation of 3D registration, which will encounter a more significant change with respect to current registration because it will also cover the steps after the submission of a 3D geometrical representation: how will this be managed in the cadastral database(s), how can users (within and outside the Kadaster) access this 3D information? Handling this kind of rich 3D information is much more complicated than storing 3D pdf's and make them available after selection in the 2D cadastral map and requires therefore further research.

ACKNOWLEDGEMENTS

This research is supported by the Dutch Technology Foundation STW, which is part of the Netherlands Organisation for Scientific Research (NWO) and partly funded by the Ministry of Economic Affairs, Agriculture and Innovation (Project codes: 11300 and 11185).

REFERENCES

Aien, A.; Rajabifard, A.; Kalantari, M. and Williamson, I (2011). Aspects of 3D Cadastre - A Case Study in Victoria. In proceedings FIG Working Week 2011, Marrakech, 15 p

Adobe (2012). 3D pdf technology. http://www.adobe.com/manufacturing/solutions/3d_solutions/(last accessed 29 February 2012).

Benhamu, M. and Doytsher, Y (2003). Toward a spatial 3D cadastre in Israel. In: Computers, Environment and Urban Systems, Volume 27, pp. 359-374.

Döner, F.; Thompson, R.; Stoter, J.E.; Lemmen, C.H.J.; Ploeger, H.D.; van Oosterom, P.J.M. and Zlatanova, S (2010). 4D cadastres: First analysis of Legal, organizational, and technical impact-With a case study on utility networks, In: Land Use Policy, Volume 27, pp. 1068-1081.

Döner, F.; Thompson, R.; Stoter, J.E.; Lemmen, C.H.J.; Ploeger, H.D.; van Oosterom, P.J.M. and Zlatanova, S (2011). Solutions for 4D cadastre-with a case study on utility networks In: International Journal of Geographical Information Science, Volume 25 (7) pp. 1173-1189.

Ekbäk, P (2011). Towards a Theory of 3D Property Rights–With an Application to Nordic Legislation. Nordic Journal of Surveying and Real Estate Research 8:1 pp. 65-80.

Eriksson, G. and Jansson, L (2010). Strata Titles Are Introduced in Sweden. In proceedings XXIV International FIG Congress, 2010, Sydney, 13 p.

Guo, R.; Ying, S.; Li, L.; Luo, P. and Van Oosterom, P (2011). A Multi-jurisdiction Case Study of 3D Cadastre in Shenzhen, China as Experiment using the LADM. In proceedings 2nd International Workshop on 3D Cadastres, 2011, Delft, pp. 31-50.

IFC (2012). Industry Foundation Classes Release 2x4 (IFC4) Release Candidate 3 Specification, available at: http://buildingsmart-tech.org/ifc/IFC2x4/rc3/html/index.htm

ISO/TC211(2012). ISO/TC 211 Geographic information-Land Administration Domain Model (LADM), ISO/FDIS 19152 (final draft international standard).

Kadaster (2007). European eGovernment Awards 2007, Submission case ELAN, Effective and efficient administration: Electronic Conveyancing. Online available www.kadaster.nl/pdf/Case_elan_engels.pdf.

Karki, S.; McDougall K. and Thompson R (2010). An Overview of 3D Cadastre from a Physical Land Parcel and a Legal Property Object Perspective. In proceedings XXIV International FIG Congress, 2010, Sydney, 13 p.

Lemmen, C.; van Oosterom, P.; Thompson, R.; Hespanha, J.P. and Uitermark, H (2010). The Modelling of Spatial Units (Parcels) in the Land Administration Domain Model (LADM). XXIV International FIG Congress, 2010, Sydney, 28 p.

Liat Choon, T. and Hussin, K.B (2012). Towards 3D Property Formation. International Journal of Scientific & Engineering Research, Volume 3, Issue 3, pp 1-8.

NEN 2580 (2007). Oppervlakten en inhouden van gebouwen-Termen, definities en bepalingsmethoden, available online: http://www.nen.nl/web/Normshop/Norm/NEN-25802007-nl.htm?gclid=CMy5rrS-qrACFcZJ3god_3shWA

OGC (2012). OpenGIS® City Geography Markup Language (CityGML) Encoding Standard, version 2.0, www.opengeospatial.org/standards/citygml

Olivares García, J.M.;Virgós Soriano, L.I. and Velasco Martín-Varés, A (2011). 3D Modeling and Representation of the Spanish Cadastral Cartography. In proceedings of the 2nd International Workshop on 3D Cadastres, 2011, Delft, pp. 209-222. Online available via http://3dcadastres2011.nl/documents/013.pdf

Onsrud, H (2003). Making a Cadastre law for 3D properties in Norway. In: Computers, Environment and Urban Systems, Volume 27, pp. 375-382.

Oude Elberink, S.; Stoter, J.E.; Ledoux H. and Commandeur, T. (2012). Generation and Dissemination of a National Virtual 3D City and Landscape Model for the Netherlands, submitted to the Journal on Photogrammetric Engineering & Remote Sensing (PE&RS).

Paulsson, J (2007). 3D Property Rights-An Analysis of Key Factors Based on International Experience. PhD Thesis Royal Institute of Technology (KTH), Stockholm, 351 p.

Pouliot, J.; Roy, T.; Fouquet-Asselin, G. and Desgroseilliers, J (2010). 3D Cadastre in the province of Quebec: A First experiment for the construction of a volumetric representation. In proceedings 5th International 3D GeoInfo Conference, 2010, Berlin, 15 p.

Rahman, A.A.; Hua, T.C. and Van Oosterom, P (2011). Embedding 3D into Multipurpose Cadastre. In proceedings FIG Working Week 2011, Marrakech, 20 p.

Queensland Government (2008). Department of Environment and Resource Management. Registrar of Titles Directions for the Preparation of Plans, 19 May 2008 http://www.derm.qld.gov.au/property/titles/rdpp/pdf/regdir37.pdf.

Thompson, R. and van Oosterom, P (2011). Axiomatic Definition of Valid 3D Parcels, potentially in a Space Partition. In proceedings of the 2nd International Workshop on 3D Cadastres, 2011, Delft, pp. 397-416. Online available via http://3dcadastres2011.nl/ documents/023.pdf

Stoter, J.E. and Salzmann, M.E (2003). Where do cadastral needs and technical possibilities meet? Cadastral Systems III, 3D Cadastre, P.J.M. van Oosterom and C.H.J. Lemmen (Eds.); Computers, Environment and Urban Systems (CEUS), July 2003, Volume 27, pp. 395-410. ISSN: 0198-9715.

Stoter, J.E. and Ploeger, H.D (2003). Property in 3D-registration of multiple use of space: current practice in Holland and the need for a 3D cadastre, In: Computers, Environment and Urban Systems (CEUS), Volume 27, November 2003, pp. 553-570.

Stoter, J.E. and Van Oosterom, P.J.M (2005). Technological aspects of a full 3D cadastral registration, International Journal of Geographical Information Science, Volume 19(6), pp. 669-696.

Stoter, J.E and Van Oosterom, P.J.M (2006). 3D cadastre in an international context: Legal, Organizational and Technological Aspects, Taylor&Francis, ISBN 0-8493-3932-4, 323 p.

Valstad, T (2010). After 10 Years in Waiting Norway Has a New Cadastral Law that also Includes 3D Objects, http://www.fig.net/pub/fig2010/ppt/ts05a/ts05a_valstad_ppt_4473.pdf.

Vandysheva, N.; Ivanov, A.; Pakhomov, S.; Spiering, B.; Stoter, J.; Zlatanova, S. and Van Oosterom, P (2011). Design of the 3D Cadastre Model and Development of the Prototype in the Russian Federation. In proceedings of the 2nd International Workshop on 3D Cadastres, 2011, Delft, pp. 355-375.

Van Oosterom, P.; Stoter, J.; Ploeger, H.; Thompson, R. and Karki, S (2011). World-wide Inventory of the Status of 3D Cadastres in 2010 and Expectations for 2014. FIG Working Week 2011, Marrakech, 21 p. Online available via: http://www.fig.net/pub/monthly_articles/may_2011/may_2011_vanoosterom_stoter_et_al.pdf

BIOGRAPHICAL NOTES

Jantien Stoter (1971) defended her PhD thesis on 3D Cadastre in 2004, for which she received the prof. J.M. Tienstra research-award. From 2004 till 2009 she worked at the International Institute for Geo-Information Science and Earth Observation, ITC, Enschede, the Netherlands (www.itc.nl). As associate professor at ITC she led the research group in the field of automatic generalization. She was project leader of a EuroSDR project on generalization from 2005 till 2009. Since October 2009, she fulfills a dual position: one as Associate Professor at Section GIS technology at OTB and one as Consultant Product and Process Innovation at the Kadaster. From both employers she is posted to Geonovum (the National Spatial Data Infrastructure executive committee which develops and manages the geo-standards). The topics that she works on are 3D, information modelling and multi-scale data integration. Since January 2010 she leads the national 3D pilot, a community that established a national 3D standard compliant to CityGML as a 2.0 collaboration of about 100 partners. In November 2010 she received a VIDI grant, which is a prestigious award given by the Netherlands Organisation for Scientific Research (NWO) for excellent senior researchers to start a new research group. Jantien has a wide national and international network in the areas of 3D modelling and automated generalization. She is Chair of the EuroSDR Commission Data Specifications.

Peter van Oosterom (1963) obtained an MSc in Technical Computer Science in 1985 from Delft University of Technology, The Netherlands. In 1990 he received a PhD from Leiden University for this thesis 'Reactive Data Structures for GIS'. From 1985 until 1995 he worked at the TNO-FEL laboratory in The Hague, The Netherlands as a computer scientist. From 1995 until 2000 he was senior information manager at the Dutch Cadastre, were he was involved in the renewal of the Cadastral (Geographic) database. Since 2000, he is professor at the Delft University of Technology (OTB institute) and head of the section 'GIS Technology'. He is the current chair of the FIG joint commission 3 and 7 working group on '3D-Cadastres' (2010-2014).

Hendrik Ploeger (1965) studied law at Leiden University and the Free University of Amsterdam, The Netherlands. In 1997 he finished his PhD-thesis on the subject of the right of superficies and the horizontal division of property rights in land. He is associate professor both at Delft University of Technology (OTB Research Institute) and Leiden University and holds the endowed chair in land law and land registration at VU University of Amsterdam. His research expertise focuses on land law and land registration, especially from a comparative legal perspective.

CONTACTS

Jantien Stoter
Delft University of Technology
OTB Research Institute for the Built Environment
GIS Technology Section
P.O. Box 5030 2600 GA Delft
&
Kadaster
Hofstraat 110
7311 KZ Apeldoorn
THE NETHERLANDS
Tel. +31 15 2781664
E-mail: J.E.Stoter@tudelft.nl
Website: http://www.gdmc.nl

Peter van Oosterom
Delft University of Technology
OTB Research Institute for the Built Environment
GIS Technology Section
P.O. Box 5030
2600 GA Delft
THE NETHERLANDS
Tel.: +31 15 2786950
E-mail: P.J.M.vanOosterom@tudelft.nl
Website: http://www.gdmc.nl

Hendrik Ploeger
VU University Amsterdam, Faculty of Law, Leiden University, Faculty of Law &
Delft University of Technology
OTB Research Institute for the Built Environment
Geo-Information and Land Development Section
P.O. Box 5030
2600 GA Delft
THE NETHERLANDS
Tel.: + 31 15 2782557
E-mail: H.D.Ploeger@tudelft.nl
Website: http://www.juritecture.net