Initial Analysis of the Second FIG 3D Cadastres Questionnaire: Status in 2014 and Expectations for 2018

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Key words: 3D Cadastres, Questionnaire, 3D Real-world, Z Coordinates/Height Representation, Temporal Data, RRRs (Rights, Restrictions and Responsibilities), Cadastral Database, Survey Plans, Dissemination

SUMMARY

In this paper we present the initial analysis of the second FIG 3D Cadastres questionnaire, spanning the years 2014-2018. The first version of the 3D Cadastres questionnaire was conducted in 2010 and collected the status of 2010 and the expectations or ambitions for 2014. Most of the FIG 3D Cadastres working group members had completed the 2010 questionnaire. Four years after the first questionnaire, the second FIG 3D Cadastres questionnaire has been disseminated. All members of the FIG 3D Cadastres working group were requested to complete before 1 October 2014 the second questionnaire in order to create an inventory of the 2014 status (and expectations for 2018). In total 31 completed questionnaires have been received by time of conducting the initial analysis as described in this paper. Similar to the first questionnaire, it is likely that there will be some completed questionnaires that will arrive later. As several new countries participated in the second questionnaire, it can be concluded that the interest is further growing. From the completed questionnaires 2014-2018, it can further be concluded that there has been significant progress on nearly all aspects of 3D Cadastres: legislation, initial registration of 3D parcels, 3D cadastral data management, and dissemination. Of course, there is quite a large difference between the individual countries: ranging from no progress to realizing a full implementation of 3D Cadastre during the last 4 years.

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1. INTRODUCTION

In this paper we report on the second FIG 3D Cadastres questionnaire 2014-2018. The first version of the 3D Cadastres questionnaire was conducted in 2010 and collected the status of 2010 and the expectations or ambitions for 2014. Most of the FIG 3D Cadastres working group members have completed four years ago the 2010 questionnaire, which can still be found at: http://www.gdmc.nl/3DCadastres/participants/ by clicking on the 2010 column of the country/ state/ province. The 2010 responses were analyzed and one of the main conclusions was (van Oosterom et al. 2011, Karki 2013) 'Despite all research and progress in practice, no country in the world has a true 3D Cadastre, the functionality is always limited in some manner; e.g. only registering of volumetric parcels in the public registers, but not included in a 3D cadastral map, or limited to a specific type of object with ad hoc semi-3D solutions; e.g. for buildings or infrastructure.'.

Now four years later the second FIG 3D Cadastres questionnaire has been disseminated (April 2014). All members have been requested to complete the new questionnaire in order to create an inventory of the 2014 status (and expectations for 2018). Table 1 shows the number of completed responses for both the first (2010-2014) and second (2014-2018) questionnaire. It is interesting to note that there are a number of new countries completing the questionnaire; showing the globally growing awareness. There are also countries that did complete the 2010-2014 questionnaire, but not the 2014-2018 questionnaire. It is difficult to assess the reason, but on the average it may be safe to assume that in these cases there are no big changes compared to four years ago.

Table 1. Completed questionnaires 2010-2014 and 2014-2018

Questionnaire completed	Countries, Jurisdictions
Both 2010-2014 and 2014-2018	Australia/Queensland, Australia/Victoria, Brazil, Canada/ Quebec, China, Croatia, Cyprus, Denmark, Finland, Germany, Greece, Hungary, India, Israel, Kenya, Macedonia, Malaysia, Nigeria, Norway, Poland, South Korea, Spain, Sweden, Switzerland, Trinidad and Tobago, Turkey
Only 2014-2018 (new)	Costa Rica, Czech Republic, Portugal, Serbia, Singapore
Promised 2014-2018	Argentina, Ecuador, The Netherlands
Only 2010-2014 (no feedback received)	Austria, Bahrain, France, Indonesia, Italy, Kazakhstan, Nepal, Russia, United Kingdom

All results are again made available on FIG 3D Cadastre website (on the webpage with working group participants: http://www.gdmc.nl/3DCadastres/participants/ and click on the 2014 column) and these completed questionnaires will further support the sharing of 3D

Cadastral experiences and related knowledge. Both the collection of responses to the 2010-2014 and the 2014-2018 questionnaires will assist decision makers, surveyors, law makers, developers, and researchers of 3D Cadastre by providing them with a snapshot of the past and current states of implementation of 3D Cadastre as well as the progresses in key development areas made by cadastral jurisdictions over time. It will further assist in correlating the progresses in 3D cadastre implementation to the maturity in juridical, institutional and technical framework.

The remainder of the paper is organized as follows. Section 2 explains the organization of the improved questionnaire 2014-2018. In Section 3 we will analyze the status of 3D Cadastres in 2014 as described in the new questionnaire 2014-2018. Also very important are the expected developments for 2018, which will be studied in Section 4. Finally the paper is concluded in Section 5 with the main findings and trends that have been identified.

2. ORGANIZATION OF IMPROVED QUESTIONNAIRE 2014-2018

The structure of the questionnaire in 2014 was kept as similar as possible to the previous one in 2010 (including the numbering of the questions). The first questionnaire consisted of the following nine sections: 1. General/applicable 3D real-world situations, 2. Infrastructure/ utility networks, 3. Construction/building units, 4. X/Y Coordinates, 5. Z Coordinates/height representation, 6. Temporal Issues, 7. Rights, Restrictions and Responsibilities, 8. DCDB (The Cadastral Database), and 9. Plans of Survey (including field sketches). Keeping the structure similar will enable tracking the changes over time. However, we also improved the questionnaire in a number of areas and decided to make the following changes:

- new section 10 on Dissemination of 3D Cadastral information,
- new section 11 on Statistical information (as there are now operational 3D systems),
- new section 12 on Reflection (and comparison to the 2010 situation),
- a few new questions and some clarified questions in other sections, and
- it was tried to apply more standard terminology (LADM, ISO 19152: 2012).

The new section 10 on Dissemination of 3D Cadastral Information provides an understanding of the mechanisms of distribution of cadastral data, both in 2D and 3D. Section 11 on Statistical information assists in numerical analysis of the 2D and 3D spatial units as well as serve as a benchmark for the analysis of similar data in 2018. Section 12 on Reflection is added to assist in judging the expected progress versus the realized developments for those participants who responded to the 2010 questionnaire.

3. PRELIMINARY ANALYSIS OF THE STATUS IN 2014

In this section the status of 3D Cadastre in 2014 is analyzed for all 31 countries which provided their responses to the second questionnaire (in time). The next 12 subsections correspond to the 12 sections of the questionnaire (as explained in Section 2 above).

3.1 General/applicable 3D real-world situations

This part of the questionnaire refers to the applicable 3D real-world situations to be registered by 3D parcels. It also addressed the types of 3D geometries, which are considered to be valid

3D representations for these parcels. In the majority of the countries, if a 3D parcel does exist (conceptually), then in most of the cases it is related to a (planned) construction, but exception are Australia, Canada, China, Finland, Israel, Malaysia, and Portugal. There is no consensus on the fact whether a 3D parcel should be connected or may consist of multiple parts. However, the majority of countries assume connected single part 3D parcels (some countries that allow multi-parts: Australia, Croatia, Cyprus, Denmark, Germany, Norway, Portugal, and Sweden). Natural resources are indeed in quite a number of countries part of the land administration, but quite seldom with a 3D representation. Spatial plans are usually not part of the land administration, but there are exceptions: China, Croatia, and Denmark.

3.2 Infrastructure/utility networks

This refers to the situation where an infrastructure network is considered to be defined within the land administration. For example, in some jurisdictions, an underground network might be privately constructed for the purpose of leasing space in it for other organizations to run cabling. In this case, a network, or part of that network may be considered to be a real estate object.

In the majority of countries the networks are not part of the land administration as cadastral objects with own cadastral identifier (‘parcel number’). A few exceptions are Denmark, Macedonia, Serbia, Sweden, and Switzerland and the Netherlands as known from other sources (Döner et al, 2011). It must be noted that quite a number of countries do show utility network lines of the cadastral map (in 2D); e.g. Finland; see Figure 1.

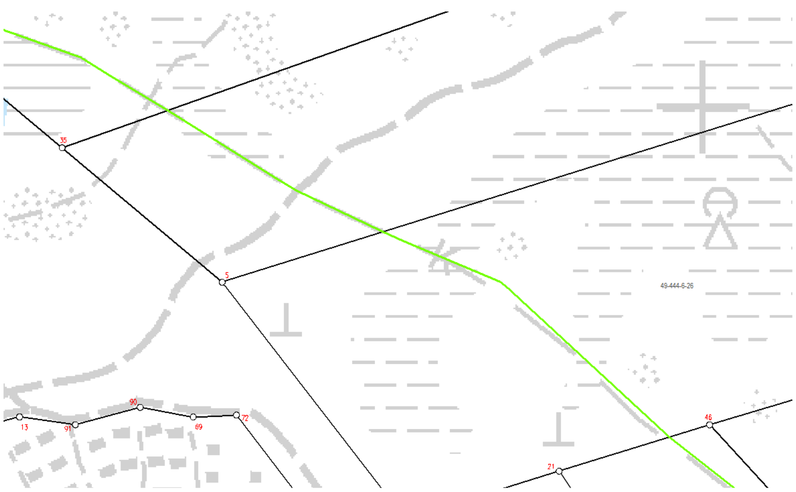

Figure 1. Example from Finland showing gas pipeline in green on the, operational, cadastral map (source http://www.gdmc.nl/3DCadastres/participants/3D_Cadastres_Finland2014.pdf)

3.3 Construction/building units

This part of the questionnaire refers to 3D properties that are related to physical constructions such as apartment (condominium) buildings. The most important construction being registered by the respondents is an apartment unit. Also other types of building units are mentioned, e.g. houses; apartments; garages; storages; shops (either on streets or within shopping centres); industrial buildings; cellars. The individual units are often defined by the actual walls and structure of a building, rather than by meters and bounds, often with a unique

identification. Some respondents do report on registration of other objects like for example large and complex buildings and general constructions (Australia Queensland), other constructions (Sweden), Underground 3D space, Overhead arch, Metro (China).
Korea has plans to accommodate the registration of bridges, tunnels and complex buildings under roads in 2018.

3.4 X/Y Coordinates

With respect of the guarantee of x/y coordinates by survey plans, we see some diversion. Plans of survey in China, Costa Rica, Switzerland (and some others) guarantee x/y coordinates. However, most of the respondents indicate that the x/y coordinates are not guaranteed by the plans. Also in line with what was concluded for the constructions, several respondents accommodate parcels without geometry, i.e. defined by walls of a building.

3.5 Z Coordinates/height representation

As with x/y coordinates, also the z information of the building units is often known via the physical structure. But also the z value is often available, i.e. as local ground heights, for example Poland, Hungary, China, Costa Rica, Malaise, Serbia, Singapore and some others. In some countries the z coordinates are reduced to a standard datum, examples are Poland, Hungary, Singapore, Malaysia and Australia Queensland. Several cadastres also store the height surface of the whole country.

3.6 Temporal issues

Under this section the questionnaire deals with the temporal aspects of the cadastre in relation to the 3D registration. E.g. the question if the temporal aspects are part of the definition of the (2D or 3D) parcel, and the question if in time moving parcels are allowed.
The temporal aspects do not seem to be a prominent part of the cadastral registrations at the moment. Generally the temporal aspects are no part of the parcel definition, with the exceptions of India and Spain. In three countries is it reported that moving parcels are allowed (Denmark, Greece and India). More particular, reference is made to rivers and wetlands (for India). For the aspect of the integration of spatial and temporal representations into a single 4D space/time representation most countries answer negative. For Greece mention is made of temporal data recording in a limited number of cadastral offices. In Switzerland the first steps are made towards this integration.

3.7 Rights, restrictions and responsibilities

Under this section the questionnaire deals with the registration of rights, restrictions and responsibilities in relation to 3D registration. E.g. the characteristics of the registration (title registration or deed registration), where the registration of 3D parcels is done (land registry or cadastral mapping agency), the responsibility of the correctness of the 3D boundaries
In most cases the registration is held by the land registry. An exception is for instance Singapore where the cadastral mapping agency is responsible. In Sweden some large municipalities are responsible for their own property formation, under supervision by Lantmäteriet (Swedish Cadastre).
The responsibility for the correctness of the 3D boundaries lies in most countries with the authority that is responsible for the land registration. Only in the case of Quebec (Canada), Denmark, Greece (however with a verification by the national cadastre & mapping agency)

and Kenya the surveyor is mentioned, while for Croatia it will be the person who produces the document for registration.

For the question if paper-based titles or deeds or proof of ownership are supplied, for all countries this question had been answered affirmative. However if this includes depictions in 2D or even 3D has been answered differently. In some cases 3D information is available, but this can also be in writing (only text, e.g. Brazil and Portugal) instead of e.g. the use of floor plans for apartments or 3D survey plans.

3.8 DCDB (the Cadastral Database)

In this section, the questionnaire deals with issues and current practices around the Digital Cadastral Database (DCDB). The questions attempt to discover whether there has been any implementation of the ISO 19152 LADM based schema in the database, understand whether there is any 3D representation in the database in any form, how they are stored, represented, viewed and queried, possibilities of 3D storage and the data structure as well as validation strategies for 3D.

As the ISO 19152 LADM has been around for a short period now and most cadastral jurisdictions that have a formal DCDB have been around for much longer, of the 29 responses 19 jurisdictions did not have their database schema completely aligned and implemented to the LADM at the moment, 5 mentioned low-level compatibility and 4 were unknown. Croatia mentioned that research showed their DCDB might be closely aligned with the LADM, Czech Republic mentioned low level conformance with LADM, Greece was compatible with INSPIRE while 5 jurisdictions including Queensland mentioned that they expected it by 2018. The DCDB was capable of storing 3D data in China and Costa Rica, Queensland stored 3D data as projected 2D while 21 jurisdictions did not store 3D in the database. In Queensland 3D data is stored in the DCDB as projected footprints in 2D and viewed as color coded 2D objects, Croatia mentioned 3D information stored as descriptive text in the DCDB. Overall there was no strong indication of actual 3D geometry in the DCDB. Three jurisdictions including China mentioned that it was currently possible to store 3D geometry in their database, Czech Republic mentioned theoretically possible while all the rest responded with a no or not applicable. China also mentioned that it was possible to manage a 3D topological structure in the DCDB while for the remaining jurisdictions it was not possible.

While China has rules or constraints specific to 3D in the DCDB, 3D data is not validated inside the DCDB in any other jurisdiction. Germany mentioned inclusion of constraints based on ISO 19107, but since 3D was not stored in their database, it can be inferred that the constraints was external to the DCDB. Some jurisdictions like Queensland, Quebec did a manual validation of paper-based plans. Queries on the database was done on 2D only in most jurisdictions, even when a footprint of the 3D was stored as 2D. China and Costa Rica mentioned possibility for querying of 3D content, but for the rest of the jurisdictions there was no way of performing a 3D query on any of the current databases.

Jurisdictions that have a formal DCDB used their own schema to suit local conditions on off-the-shelf database products to maintain their database; some were paid software like Oracle in China, Quebec, Croatia etc. or free software like INGRES in Queensland, PostgreSQL such as in Germany or developed to suit such as in Croatia. Software like CAD, GIS products (e.g. ESRI or Microstation) was used for editing. While most jurisdictions did not make cadastral information publicly available, some jurisdictions like Quebec, Queensland, Costa Rica disseminated cadastral data online, buts none had 3D functionality. The question on DCDB data model was misunderstood by some based on their responses, so it is a learning for the next phase to clarify this question and also to identify other similar questions where the responses show that the question was not clear enough. Where the responses were clear, it showed a variety of data model in use, such as Object oriented for 9 jurisdictions including China, Queensland, Multi-layers 6 jurisdictions including Quebec and a combination of both for 3 jurisdictions.

3.9 Plans of survey

In this section, the questionnaire deals with how 3D is represented in survey plans, legislative support around representation of 3D on survey plans, whether sketches form part of the survey plan, how they are connected to real world objects in the plan, validation of 3D parcels, the techniques for data capture and post-processing, the transactions that can take place on a 3D parcel, the presence of any technical guidelines to support 3D field survey, the use of building construction plans and who is responsible for the creation of survey plans.
Although, most jurisdictions did not show 3D information on a cadastral plan, some like Queensland, China, Germany, Malaysia, and Sweden did. Quebec, Canada and Trinidad and Tobago display a vertical profile (see Figures 2 and 3), while Croatia had 2D plans with 3D textual information. Even if 3D survey plans are not created, apartments are registered in jurisdictions like Brazil, while 3D is not yet supported in jurisdictions like the Czech Republic, Finland, Hungary, India, Israel etc. Macedonia mentioned that infrastructure objects are registered on the map however it is not clear whether these infrastructure objects are in 3D. Poland mentioned that although the survey plans did not have 3D parcel representations there were some example or prototype 3D plans available.

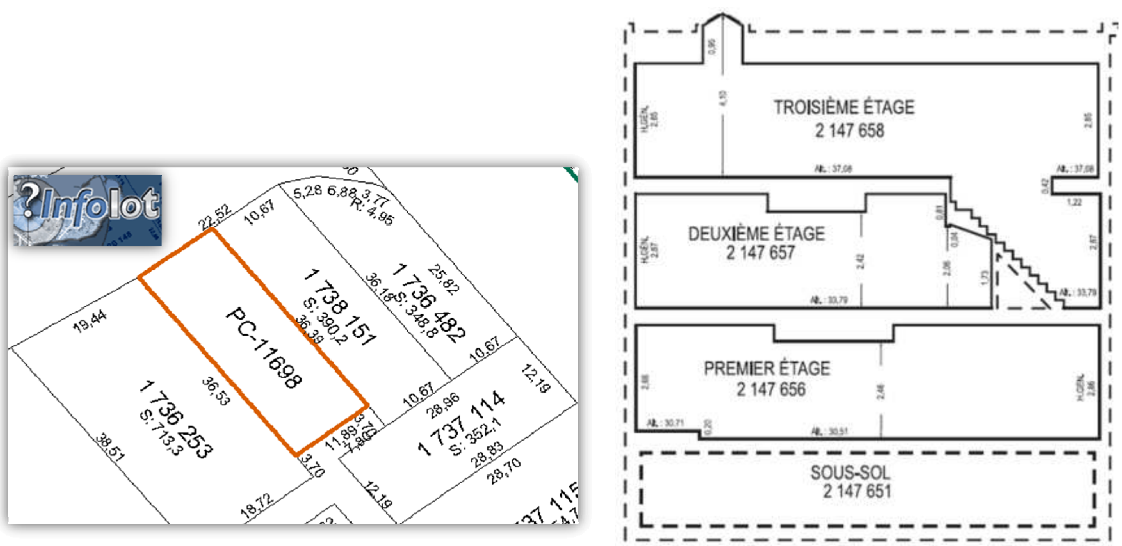

Figure 2. An example from Canada. Left: the cadastral plan that refers to a complementary plan (PC), Right: a vertical profile of the superimposed properties extracted from the PC plan (from questionnaire http://www.gdmc.nl/3DCadastres/participants/3D_Cadastres_CanadaQuebec2014.pdf)

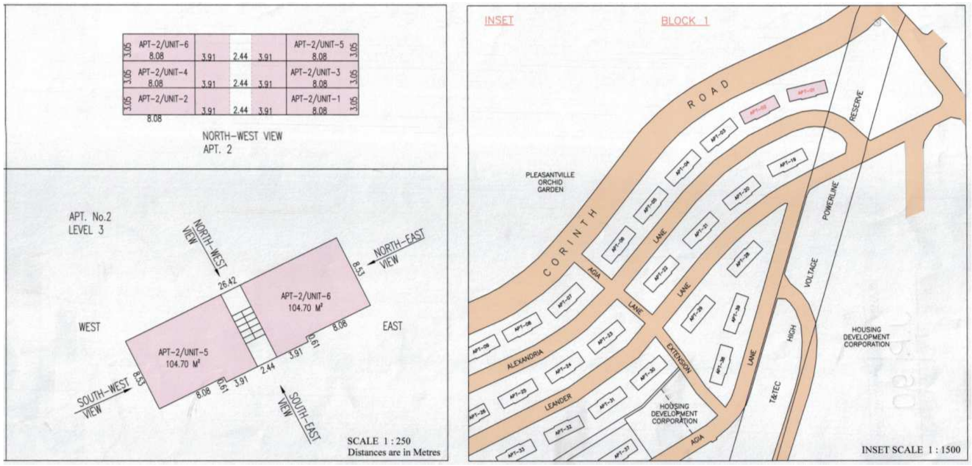

Figure 3. An example from Trinidad and Tobago. Top left: vertical profile, Bottom left: floor plan third floor of apartment no. 2, Right: overview map, also note reserve for high voltage powe line (from questionnaire http://www.gdmc.nl/3DCadastres/participants/3D_Cadastres_TandT2014.pdf)

Queensland and Malaysia displays volumetric data as isometric views, China as coordinates, lines polygons and solids, Germany as geometric objects and attributes. Sweden displays construction plans with heights relative to the building and each floor is represented in a separate diagram. While there is some legislative support, whether specific to 3D as in Queensland, and Trinidad and Tobago, or slightly connected to 3D as in Quebec, Canada, some jurisdiction like Croatia mentioned no current legislative support for 3D. Greece has legislative requirement for recording of height but there is no provision for 3D.

Queensland allows sketches as part of a building format plan, however the sketch is not stored in the DCDB. Macedonia allows sketches for condominiums, while Spain sketches each floor. Plans are created in most jurisdictions with connections to real-world objects. Some jurisdictions like Queensland and Quebec mentioned connections to a height datum. Malaysia mentioned no connections to other real-world objects.

Most jurisdictions perform a manual or visual validation of survey plans, however Denmark mentions that it is the responsibility of the surveyor to ensure that the plans are correct. Terrestrial surveying seems to be the method of choice for capture of field data, however jurisdictions like Costa Rica use orthophotos and laser scanning for field data capture although they are not specifically used for cadastral purposes.

While not many jurisdictions had technical manuals or guidelines for the surveyors, some like Queensland had specific manuals for surveyors to assist them with plan creation. Singapore mentioned that although there were no 3D survey plans, a technical manual to support 3D data capture has been developed. The question on whether building construction plans are used to create cadastral plans aims to consider the possibility of using Building Information Models (BIM) to create 3D plans in the future. While most jurisdictions do not use the building construction plans to update their cadastre, Costa Rica mentioned that it is used; see Figure 4. In most jurisdictions private surveyors perform cadastral work. In some jurisdictions like China, India, Sweden, the government surveyors are responsible for the preparation and lodgement of survey plans, while in Germany, Kenya, Trinidad and Tobago it is a combination of both.

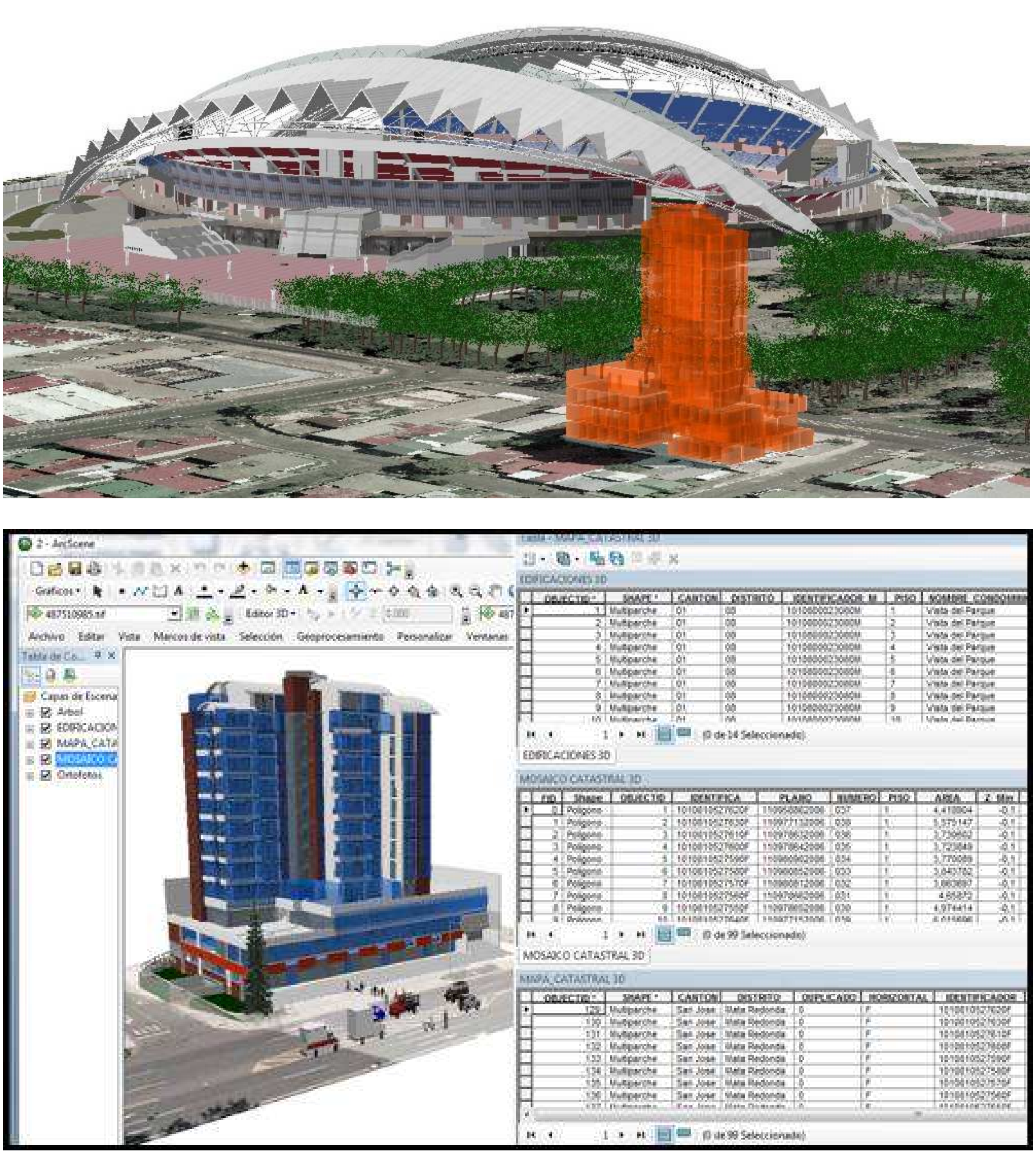

Figure 4. Use of BIM in Costa Rica to update the Cadastre: top, both for the complex building (in orange in the front) and stadium (in the back), 3D parcels are registered, bottom: more spatial and administrative details from the complex with many building units (source: Andres Hernandez Bolaños).

3.10 Dissemination of 3D cadastral information

On the question on the availability of a general purpose web-based dissemination of 2D cadastral (graphical or text) information (e.g. a portal for the public or for professionals) most countries replied positive. Mentioned formats for data dissemination are: SVG (in house), GoogleEarth, WMS/FWS based and KML.

3D data dissemination via a portal was reported from Québec, Canada (PC plans can be visualized as CGM and CPC lite image); Brazil (includes 3D data); China (AutoCAD, 3D PDF or SketchUp files); Croatia (3D data in text format – separate parts of real property); Spain (KML in Google Earth for 3D (4D) view (3D of buildings based on floor plans and estimated average floor height), Sweden (XML and ÖFF a self made format); one canton in Switzerland (with Mutlipatch Esri, 3DS, CityGML, kmz, obj as formats); and Germany reports CityGML, 3D Shape, KML, DXF, On demand: VRML, 3DS and 3D Pdf as formats in 3D. Some repeatedly expected formats for countries in 2018 are 3D pdf and 3D LandXML,

On the question about specific cartographic styling rules for representing 3D cadastral plans, or to represent 3D cadastral objects on 2D cadastral maps the following could be found in the answers:

- the surveying handbook has defined some styling rules for preparing 2D plans;
- building subdivision guidelines (on line);
- by dotted lines, special surface texture and text (e.g. “\1:32\”);
- issued as Director General Circulars for preparing Certified Plans;
- there are specific cartographic styling rules to represent 3D cadastral objects on 2D cadastral maps; and
- there are instructions (Instructions pour la présentation des documents cadastraux relatifs à la mise à jour do cadastre du Québec (version 3.01)) for presenting the cadastral plan and vertical cadastre.

The question on specific cartographic styling rules for 3D cadastral maps (models; e.g. as disseminated in 3D pdf) was answered negative in most cases.

3.11 Statistical information

This group of questions provided a rich overview of information relevant for the development of 3D Cadastre.

First question is about the smallest 2D and 3D parcel that is present/ allowed to be registered in the land administration? In case of planar co-ordinate systems (and also in case of geographic reference) a parcel or volume can not be smaller then the square of smallest unit in (linear) resolution. In 3D a similar rule is valid, but the cubic of smallest linear unit. This is the smallest possible unit that can be represented in the Information System; in reality such a unit has no meaning. The question did find a range of answers related to representation of cadastral objects in the Information System (1cm * 1cm * 1cm; a few milimeters, 0.1 m^2; ‘no lower limit’; or ‘not defined’) or to the situation in reality (1m^2, ‘No limits as long as boundary marks can be planted’ and many minimum parcel sizes related to regulations, especially urban planning regulations). A similar question concerned the largest 2D and 3D parcel that is present allowed to be registered in the land administration? Answers range from the size of real objects (“biggest parcels are in the forest (state land)”; “limited by parent block scale”; “a subway channel”) to biggest known objects (“38838094 m^2” or “22855683 m^2”); relation to regulations (“No legal limits”) or just “no limits”.

The next question in this “statistical series” is again on size (area/ volume): what is the typical (or average) size of 2D and 3D parcels which are registered in the land administration? Subdivide by nature of 3D parcel when relevant (e.g. related to building, apartment, airspace, tunnel,…). A significant variation is reported; also in 3D objects as in Australia, Queensland. In one case (Kenya) there was a link to the jurisdiction.
The question (11.4) on how many 2D and 3D parcels do you currently have in your land administration provided again a wide variation; the table below gives an impression (not all countries had data available):

Table 2. Statistics on number of parcels

Question 11.4.	**Status 2014**
Australia Queensland	2,228,119 2D parcels 291,916 building format lots 2,874 volumetric lots
Australia Victoria	Near 5 million.
Canada Québec	In the Cadastre du Québec (CQ), there is actually ~235 000 3D lots and ~2 800 000 2D lots. About 19% of the lots are not yet compiled in the CQ
China	2D 140,000 3D 300-400
Croatia	There are 1.600.000 2d parcels (whole island). There are also 150000 registered units (apartments)
Cyprus	2D = 14.440.938; 3D = 100.000 approx.
Czech Republic	21 067 103 (2D parcels)
Denmark	There are 328.899 condominiums in Denmark per. 1/6-2010
Finland	over 1 million
Germany	2D-parcels: ca. 10 400 000 3D parcels: 0; 3D Buildings: 2 500 000
Hungary	2D = 7,4 million + 2,4 million condominium units 3D = Not available
India	There are approx. 0.6 million villages and more than 600 districts in India so it cannot be calculated as per now
Israel	~ 800K 2D parcels
Macedonia	Approximately 4.9 millions 2D parcels, no information for 3D
Malaysia	2D – Approximately 7.8 million parcels
Poland	35 800 992 - 2D parcels (31.12.2013)
Portugal	Roughly 17 millions, 1/3 of which have been 2D surveyed in the field
Serbia	18 780 716 2D Parcels
Singapore	At present 142842 2D land parcels and 1492980 strata parcels
Spain	52 millions parcels and 38 millions urban real state
Sweden	2D parcels: 3258911. 3D parcels: 870
Switzerland	There are approx. 3’830’000 2D and about 1’000’000 3D parcels.
Trinidad and Tobago	2D = 100,000 3D = 10,000

Australia, Queensland, expects a significant increase in 3D representations in 2018: 2,500,000 2D parcels, 350,000 building format lots 10,000 volumetric lots. Same for Germany: 3D Buildings: 8,500,000.
When it is about the year of starting registering 3D parcels in the land administration there was a range from 1950s (Australia, Victoria) till recently. Several countries mentioned that 3D parcels are not registered as such (Germany: 3D: No parcels, only buildings; Greece: No 3D parcels are registered. Units with 3D aspects (e.g. SRPO, mines) recorded since 2010; Hungary, India, Israel, Portugal, South Korea; Singapore filled “not applicable”).

When it is about the ratio of 3D parcels in rural vs. urban areas there is a very clear direction to urban areas. Most questionnaires included cities with significant numbers of 3D Parcels (Spatial Units).
Data on: (a) Size of jurisdiction in square kilometres, (b) Current number of 2D parcels, (c) Current number of 3D parcels, and: (d) Current population resulted in the following DRAFT overview are presented in Table 3 – further verifications are needed before final publication of this table.

Table 3. Draft overview of general statistics

	Size of jurisdiction in sq km	**Number of 2D parcels**	**Current number of 3D parcels**	**Current population**
Australia Queensland	1,730,648	2,228,119	294,790 (291,916 building format, 2,874 volumetric)	4.7million
Australia Victoria	227,416 km²	~3,122,000 (the number of land parcels)	~435,000 (strata parcels)	5,821,300
Canada Québec	close to 1,7 millions km² of which 92% is public land.			8,2 millions
China (….)	2,000	140,000	400	16,000,000
Croatia	56.542	14.440.938	100000 approx.	4.284.889
Cyprus	924	1.600.000	150.000 (registered)	840.000
Czech Republic	79000	21 067 103		10.2 mil.
Denamrk	44.000	1.600.000	150.000	
Finland	338434,73	Over 1 mio	0	5.5 mio
Germany	70.551,57	10 400 000	0	12 604 000
Greece	131 944	Approximately 38 000 000 rights including 2D parcels, 3D parcels (although there is no legislation introducing 3D property in Greece), and joint rights	Approximately 38 000 000 rights including 2D parcels, 3D parcels (although there is no legislation introducing 3D property in Greece), and joint rights	10 815 197 (census 2011)
Hungary	93 000	7 400 000+2,4 million condominium units		9,9 million (2013)
India				1,20 billion approx..
Israel	~22000	~800K		~8.2 million
Macedonia	25713	about 4.9		2.06 million
Malaysia	198,160 (Peninsula	7.8 million parcels		30 million

	Malaysia only)			
Poland (2013)		35 800 992	0	
Portugal	92,212	5,600,000 (roughly)		10,562,178 (2011)
Serbia	88361	18 780 716		9 024 734
Singapore	approximately 700km2	142842 + 1492980=1,635,54 1		5.47million s in June 2011
South Korea	100,266	37,925,210		50,423,955
Spain	Will be provided			
Sweden	Data for 3 cities			
Switzerland	41'285	4'040'000	1'000'000	8'161'000
Trinidad and Tobago	5,000	1000,000	10,000	1,300,000

The question: "Approximately what are the proportions of various types of the 3D parcels (related to apartments, subsurface parking, subsurface shopping centres, bridges, tunnels, airspace, utility networks, etc)?" could not be answered in most cases; except Australia, Queensland ("a best estimate is that: Most are apartments (building format lots). Amongst the volumetric lots, most are tunnel parcels, followed by overhangs into roads, division of buildings into projects (which are further subdivided into building format parcels), and mining related volumes."; Canada, Québec: About 90% of the 3D parcels are related to apartments; Cyprus: 90% apartment. Denmark provided accurate data: 30.000 dwellings, 246.000 apartments, 2290 College-apartment, 1963 Business production, 6000 Business offices, 7150 Shops, 226 Hotels, restaurants, service, 385 Banks, and 163 Cinemas, Theatres (based on documentations from 2010).

Similar problems raised in answering the next question: approximately what surface area of the jurisdiction is affected by 3D parcels (the total area of all the footprint of all 3D parcels). Queensland: Volumetric: 7.4 * 107m^2, being 0.004% of the state, BF parcels: 4.6 * 107m^2, being 0.0026% of the state. China: Approximately 8,380,855m^2. Israel: Potentially most major urban areas and areas with transportation network development. Switzerland: < 1 %. Trinidad and Tobago: 10%.

Conclusion: a very wide overview of data has been provided with different levels of detail. The provided data are interesting in relation to 3D Cadastre, but the questionnaire contents may be more specific for this group of questions. Co-operation with the cadastral template is suggested: www.cadastraltemplate.org .

3.12 Reflection (and comparison to the 2010 situation)

This section of the questionnaire started with the question on which developments, compared to the 2010 expectations, did go faster than expected? In relation to this Croatia noticed the registration of separate parts of real property (office and apartments) of new buildings. Greece reported about the new act on Surveying and Mapping. In Kenya some efforts are being made to first automate the 2D cadastre and then also to start implementing 3D digital cadastre. Macedonia talks about registration of infrastructure objects as 3D properties. Portugal says that 3D cadastre is still very much a scientific research topic. South Korea replies that it is not easy to change 2D parcel to 3D parcel because of responsibilities. Sweden reports that large building projects are using 3D property formation for tunnels, garages, street overhang, etc. An example is the New Karolinska hospital in Stockholm. Switzerland noticed that the surveying methods and the technology developed even faster than expected and also that huge amounts of 3D data are collected - data can today be handled and the required hardware is more affordable.

The next question was the similar - but now, which developments did go slower than expected? As can be expected there was a broad range of answers, with some interesting issues. For Queensland, Canada this is about the ability to lodge digitally. China speaks about law and policy; Croatia about registration of public utility infrastructure and Nigeria about general government funding and good governance related to planning and development. Poland sends the message that the 3D cadastre ideas got quite a big popularity, especially (but not only) in academic community but they have not not followed by legal regulations so far. South Korea is focusing on visualization of the 3D parcel. Sweden is still busy with the restructuring towards object orientation of the real property register which is not finished yet – the formation of ownership apartments has not accelerated as much as expected; probably due to a well-functioning site-leasehold system in Sweden and the general economic crisis. Switzerland mentiones the amendment of the legal framework towards a 3D cadastre which came more or less to a halt this spring. However the need of people working in the sector of construction and other users of the underground is still there. There are still some important questions regarding 3D GIS have not been answered, like "clean" 3D topology.

The next reflection question was formulated as follows: if some (limited) form of 3D Land administration functionality has become available, what are the observed benefits? And for who? Quebéc sees no change since 2010; decisions were made to keep the same strategy as it is currently to manage the third dimension (with complementary plans). China reports intuitive visualisation here. Croatia speaks about increased registration of separate parts of real property. Greece reports stimulation of land market and investments (e.g. mortgage market). Better functionality of Land Administration, which drives to better economy and better life for all. Israel speaks about a principal progress in the Carmel tunnels project (legal precedent). Macedonia speaks about possibilities for registration of properties rights on infrastructure objects which was not possible before, also created a form for infrastructures like tunnels to be registered outside 2D parcel which create possibility to mortgage, transfer property rights, increase security on this properties; Poland about the general building parameters enabling the apartments units general localization within the building (apartment units complex); Sweden about the benefit of easy access to information in the real property register (although the GIS possibilities for e.g. analytical purposes are limited due to no full 3D (volume) registration) and Switzerland about digitally accessible 3D data in land register in a few cantons and city models for planning in several cities.

The answers to the question on the (top-3) challenges of issues to be addressed to realize further 3D Land administration progress are provided in table 4 below. A lot of ambitions are included,... and inspirations!

Table 4. Top 3 Challenges

Country	Challenge 1	Challenge 2	Challenge 3
Australia/Queensland	3D ePlan submission	Validation	Storage mechanism
Australia/Victoria	3D data acquisition	3D data visualisation	3D data maintenance
Brazil	Improvement of 2D land administration	Training of professionals with expertise in 3D	Integration of data
Canada/Quebéc	Spatial representation for any kind of overlapping properties	Integrated strategy for immatriculated and not immatriculated real estate	
Croatia	Land policy Real property taxation	The resolution of legal uncertainty inherited from past	
Cyprus	Political decision	Technical approach for data capture	Data model design
Denmark	Modelling 3D ownership/parcels		
Finland	Buildings		
Greece	Modelling 3D legal situations	Modelling new rules/ business procedures	Defining 3D surveying requirements
India	Political will	Administrative Hurdles	Technical Manpower
Israel	Development of appropriate legal framework		
Macedonia	Introducing 3D properties in all 3D situations	Defining procedures for administrating 3D properties	Visualisation of 3D property
Nigeria	Awarenes	Investment by government	Capacity building
Poland	Formal definitions of 3D cadastral objects	Pilot project	Creating circulars for 3D cad surveys
South Korea	Visualization	3D Surveying	3D Geo-database
Spain	Change current data model and tools (if needed)		
Sweden	To further the formation of 3D properties	Creating 3D ownership apartments in existing tenancy apartments	
Switzerland	Convincing lawyers to change the law to vertical limitations	Find a possible funding for the 3D data capture process.	Organize the work according to the need of practice.
Trinidad and Tobago	Development of rules for representation	Submission of digital plans	Capacities of staff

4. PERSPECTIVE FOR 2018

Similar to the first questionnaire only a limited number of countries completed the column with their expectations for 2018 (other than 'no change', or 'hard to estimate' type of anwers). These included: Australia (Queensland, Victoria), China, Croatia, Denmark, Finland, Hungary, Israel, Malaysia, Poland, Singapore, Switzerland, Trinidad and Tobago. One of the most tangible indicators is the development of 3D capabilities is the DCDB, as this the core of a 3D Cadastre.

With two co-authors from Australia, we will now further focus on this country. Responses to the questionnaire were received from Queensland and Victoria. This section analyses the changes and expectations in response from 2010 to 2014 and expectations for 2018. It provides a short description of the current status of the cadastre in Queensland and Victoria with particular relevance to 3D aspects and including changes and expectations.

In 2010 all 3D parcels were constrained within a 2D parcel, and it was expected to see some examples where the constraint was violated, however in the intervening four years it has not happened. To encourage freedom of 2D-3D creation the policy has now shifted to not enforcing any such constraints.

It was expected that 3D would be defined in LandXML for digital submission, but even though there has been significant progress in digital submission of 2D data, digital submission of 3D data is not yet fully defined. In Queensland, new tenures such as carbon abatement zones have been added to the DCDB however they are considered as individual layers and are treated similar to easements and not related to 3D.

There have been specific examples and further clarity on dealing with network objects. Survey plans are created for each part of a network object such as a tunnel that intersects with a freehold 2D surface parcel, but if it passes under government land such as road or river, a parcel is not created for it. The entire network has a single title with all the identifiers of the individual spatial units listed in the title including any encumbrances. The network can be viewed as a single object in 2D in the DCDB but since they are composed of individual spatial slices, they cannot be traced in the database as a single network object.

In Queensland, volumetric parcels continue to be related to the Australian Height Datum (AHD) but it has still not been able to store relative and absolute z coordinates in the DCDB, whereas in Victoria, 3D data is not acquired by surveying in the field but cross sections shown in the plans. 3D parcels are still not stored in the DCDB and although it was expected that validation rules for 3D objects in the database would be developed by 2014, it is yet to materialise. Plans are still paper-based but those containing 2D objects are digitised to simulate digital submission, and all further databases and processes operate as if it was a digital submission. For 3D volumetric objects the 2D footprint of the 3D parcel are converted to digital form and used as digital submission. The paper-based plans are still the legal document and the point of truth; the electronic document or the DCDB is not used for court cases.

Cadastral data dissemination has included a layer on Google Earth in addition to the in-house viewing tool based on SVG. Due to the open data policy, topographic and cadastral data is now freely available to the public (through Google Globe in Queensland), and contains among others, land parcels and valuation layers with no personal information displayed. As the underlying cadastral data from DCDB does not contain 3D information, so the disseminated data in Google does not contain 3D as well. The in-house viewers display all

information related to ownership, valuation and history but is restricted to users in the department and private surveyors.
A new section of this questionnaire dealt with statistical aspects of a cadastral jurisdiction and the responses shows that 3D has become a very important part of the cadastre. There are almost three hundred thousand building parcels in Queensland, and more than four hundred thousand in Victoria which are concentrated on the major regional centres. Volumetric parcels have grown exponentially in the last four years and have reached almost three thousand parcels in Queensland. There are around 2.3 million parcels, both 2D and 3D, in an area of around 1.7 million square kilometres for a population of around 4.7 million. In Victoria, these figures are 3 million parcels, 227 thousand square kilometers and 5.8 million population. The cadastral jurisdiction has set no constraints on the minimum or maximum size of 2D or 3D parcels in Queensland, and a 1cm^3 minimum constraint in Victoria.

5. CONCLUSION

It can be concluded that there has been significant progress during the last 4 years: more and more countries have legal provision for the registration of 3D parcels, jurisdictions such as Australia/Queensland, Australia/Victoria, China, Germany, Malaysia, Sweden, Trinidad and Tobago have 3D information on their cadastral/ survey plans (while some others have vertical profiles of 3D textual information and nearly all countries have provisions for apartments), and China has even a fully operational 3D cadastral database (while some others store the 2D footprints of 3D parcels in the cadastral database). Another important trend which can be observed is the use of building information models/ construction plans to update the cadastral database, as done in Costa Rica.

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BIOGRAPHICAL NOTES

Peter van Oosterom 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. From 1985 until 1995 he worked at the TNO-FEL laboratory in The Hague. From 1995 until 2000 he was senior information manager at the Dutch Cadastre, where he was involved in the renewal of the Cadastral (Geographic) database. Since 2000, he is professor at the Delft University of Technology, and head of the 'GIS Technology' Section, Department OTB, Faculty of Architecture and the Built Environment, Delft University of Technology, the Netherlands. He is the current chair of the FIG Working Group on '3D Cadastres'.

Jantien Stoter 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 now fulfils a dual position: one as professor at Delft University of Technology, 'GIS Technology' Section (Department OTB, Faculty of Architecture and the Built Environment) 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).

Hendrik Ploeger 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 at Delft University of Technology, 'Geo-information and Land Development' Section (Department OTB, Faculty of Architecture and the Built Environment) and holds the endowed chair in land law and land registration at Free University of Amsterdam. His research expertise focuses on land law and land registration, especially from a comparative legal perspective.

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