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3D Land Administration

Current Status (2022) and Expectation for the Near Future (2026) – Initial Analysis

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3D Land Administration: current status (2022) and expectation for the near future (2026) – initial analysis

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Key words: Land Administration, 3D Cadastres, LADM, Worldwide Survey

SUMMARY

This paper refers to the creation or update, organisation and initial analysis of the results from the 4th FIG 3D Land Administration Questionnaire, as an activity of the FIG Working Group 3D Land Administration 2022-2026.

The questionnaire on *3D Land Administration* is conducted as a successor of the previous questionnaire on *3D Cadastres*, which has been conducted three times till today, by the Working Group in 2010, 2014 and 2018. The first, documented the status in 2010 and expectations back then for 2014. This was followed by the second questionnaire (status 2014 and expectations 2018) and the third one (status of 2018 and plans for 2022).

All members/ countries the Working Group have been requested to provide information about the current the status of 3D Land Administration Systems/ Cadastres (at the end of 2022) and the expectations/plans for 2026. The purpose of the survey that is has been conducted and reported in this paper, is to make an inventory of the status of 3D Land Administration at the end of 2022 and the plans/ expectations for the near future (2026) from countries all over the world.

The completed questionnaires, per country are fully available via the participants' page of the 3D Land Administration Working Group website. The responses have been analysed and reported in various publications (van Oosterom et al. 2011, van Oosterom et al. 2014 and Shnaidman et al., 2019). In total, thirty-seven (37) countries have completed the questionnaire and have been received by time of conducting the initial analysis as described in this paper. Similar to the previous questionnaires, it is likely that there will be some completed questionnaires that will be sent by the countries later.

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1. INTORDUCTION

As urbanisation rapidly increases, nowadays, the need for land, including both above and below ground developments, grows, while, at the same time, numerous restrictions are being imposed, reducing the availability for exploitation of 3D space. This leads to the interlocking structures of the built environment which result in complex overlapping Rights, Restrictions and Responsibilities (RRRs) being im- posed on land/air/marine parcels. In this scene, more and more countries are exploring the development of 3D Land Administration Systems, to better serve, the needs of their space.

An efficient and reliable land administration system is the foundation for a strong economy of a country and sustainable development. Since cadastre is perceived as the core of any land administration system, linking the three essential components therefrom: people-to-land relationships through Rights/Restrictions/Responsibilities (RRRs), it is expected to provide a complete and up-to-date information regarding parcels boundaries and the associated relations (Kitsakis et al., 2018).

However, the majority of currently operational land administration systems around the world are 2D-based, while there are various countries/ jurisdictions that have developed operational components of 3D LAS and in parallel, the topic has been the subject of much research and debate (Lemmen et al., 2003; van Oosterom, 2013; van Oosterom, 2018, van Oosterom, 2022). Part of this activity was coordinated and supported by the international community of surveyors, namely the International Federation of Surveyors (FIG) Joint Commission 3 and 7 "3D Cadastres" Working Group.

It is noted that at the FIG Congress 2022 in Warsaw the new name of the FIG Working Group was discussed during the FIG Commission 3 and Commission 7 meetings. As a result of these discussions, it was decided to include LADM (ISO 19152, the Land Administration Domain Model) within the scope of the Working Group because of the close relevance and the related advances in the field. Therefore, the new name of the Working Group is suggested to become "3D Land Administration and Land Administration Domain Model"; in short, "3D LA & LADM" and will be finalized during the FIG Congress 2023 in Orlando.

The questionnaire on *3D Land Administration* that is presented in this paper, is conducted as a successor of the previous questionnaire on *3D Cadastres*, which has been conducted three times by the Working Group, specifically, in 2010, 2014 and 2018. By sharing this information among the countries/ jurisdictions, a comprehensive inventory will be created. It is expected that cooperation will improve, by learning from the different countries and jurisdictions, to support future developments in the field of 3D land administration. It is noted that, as LADM is finding increasing recognition (Kalogianni et al., 2021), it has been further incorporated into the various sections of the questionnaire.

At the following table an overview of the countries that have participated in the questionnaires over the time, from 2010 that the first questionnaire was conducted till 2022, that the current one is under analysis, is presented. Starting with the first row, the countries or jurisdictions that have participated in all four (4) questionnaires till now are listed. At the second row, the countries that participated in 2022 are listed; in total thirty-seven (37); while those that have participated in the previous three (3) questionnaires, but not at the current one, are listed in row #3; in total four (4). To provide better insights, all the countries that have participated in the first three (3) questionnaires are listed in row #4.

At the next row (#5), the countries that have participated in the first two (2) questionnaires (2010 and 2014) are presented, as analysed by van Oosterom et al. (2014) and at row #6 the countries that participated only at the first questionnaire in 2010 are listed. Lastly, the countries that have participated for the first time at the survey in 2022 are listed in row #7.

In total, fifty-four (54) countries have been contacted to complete the questionnaire for 2022.

Table 1. *Overview of the countries that participated in the questionnaires from 2010 till 2022*

#	Questionnaire completed				Countries/ Jurisdictions that participated	Number of countries that participated
	2010	2014	2018	2022		
1	√	√	√	√	Argentina, Queensland and Victoria from Australia, Quebec from Canada, Shenzhen provincial city from China, Croatia, Cyprus, Finland, Greece, Israel, Kenya, Malaysia, Poland, South Korea, Spain, Sweden, Switzerland, The Netherlands, Trinidad and Tobago, Turkey	19
2				√	Argentina, Queensland, New South Wales, Western Australia and Victoria from Australia, Austria, Bahrain, Brazil, Quebec from Canada, Shenzhen provincial city from China, Croatia, Cyprus, Czech Republic, Denmark, Finland, Greece, Iceland, Indonesia, Indonesia, Israel, Kenya, Malaysia, Montenegro, Nepal, New Zealand, Poland, Portugal, Scotland, Serbia, Singapore, Slovenia, South Korea, Spain, Sweden, Switzerland, The Netherland, Trinidad and Tobago, Turkey	37
3	√	√	√	**NO**	Germany, Hungary, Delhi State from India, and Delta State from Nigeria NGA	4
4	√	√	√		Argentina, Queensland from Australia, Quebec from Canada, Shenzhen provincial city from China, Cyprus, Finland, Germany, Greece, Hungary, India, Israel, Kenya, Malaysia, The Netherlands, Nigeria, Poland, South Korea, Spain, Sweden, Switzerland, Trinidad and Tobago, Turkey	22
5	√	√			Argentina, Queensland and Victoria from Australia, Brazil, Quebec from Canada,	28

					Shenzhen provincial city from China, Croatia, Cyprus, Denmark, Finland, Germany, Greece, Hungary, India, Israel, Kenya, North Macedonia, Malaysia, The Netherlands, Delta State from Nigeria NGA, Norway, Poland, South Korea, Spain, Sweden, Switzerland, Trinidad and Tobago, Turkey	
6	√				Argentina, Queensland and Victoria from Australia, Austria, Bahrain, Brazil, Quebec from Canada, Shenzhen provincial city from China, Croatia, Cyprus, Denmark, Finland, France, Germany, Greece, Hungary, India, Indonesia, Israel, Italy, Kazakhstan, Kenya, North Macedonia, Malaysia, Nepal, The Netherlands, Delta State from Nigeria NGA, Norway, Poland, Russian Federation, South Korea, Spain, Sweden, Switzerland, Trinidad and Tobago, Turkey, England and Wales (UK)	37
7				**√ (new countries)**	Hong Kong, Iceland, Montenegro, Philippines	4

At the following figure, the spatial distribution of the countries that have participated in the 4th Questionnaire on 3D Land Administration is preseted.

Figure 1. *Spatial distribution per continent of the countries that have participated in the 4th Questionnaire of 3D Land Administration (current status of 2022 and expectations for 2026).*

2. STRUCTURE AND ORGANISATION OF THE 4TH FIG 3D LAND ADMINISTRATION QUESTIONNAIRE

The questionnaire aims to address the most important aspects related to 3D LAS and it occurs every four (4) years, so that important technological developments and advances in the legal aspects can be reported.

All members/ countries of the FIG 3D LA & LADM WG have been requested to provide information both regarding the current situation at the end of 2022 and the expectations/plans for 2026.

This current questionnaire is backwards compatible with the previous three, while some questions have been refined for clarification and several new questions have been added at the end of the sections, introducing the topics of BIM in land administration, 3D land administration applications and implementation of the LADM.

Currently the survey comprises of 13 sections in total, similar to the previous. The first nine (10) sections comprise of questions about the following topics:the 3D real-world situations that are being registered by 3D parcels;

1. 3D real-world situations;
2. the registration of infrastructure networks within the land administration;
3. the reference between the 3D properties and the constructions and apartment (condominium) buildings;
4. the coordinates;
5. the third dimension in terms of representation and registration;
6. the temporal issues in terms of representation and registration;
7. the RRRs and their registration at the LA system;
8. the structure and functionalities of the cadastral database;
9. the cadastral survey plans in terms of context and process and
10. the dissemination of 3D LA-related information.

The last three (3) sections refer to statistical information (Section 11), reflection and remarks from the participants of the questionnaire (Section 12), as well as their contact details (Section 13). The new questions introduced in this questionnaire aim to provide more insight about the following aspects:

1. developments related to ISO19152 LADM, specifically related to country profiles;
2. BIM-based sources used for 3D LAS registration and relevant specifications that may apply to the country;
3. operational solutions related to previous question;
4. developments related to national 3D City Models and
5. other types of objects that require both real-world time and database time to be registered at the LAS.

The questions are the following:

Question 1.23 *Has there been developed any country profile based on LADM ISO19152 ?*

(a) Does it support 2D spatial units?

(b) Does it support also 3D spatial units?

(c) Is there any provision to include/ align with the new LADM developments of the second Edition of the standard (inclusion of valuation information, marine spaces, spatial plans, interoperability/ reuse of BIM/IFC, ..)?

Question 3.14 *Are there any mandates that set specifications on the delivery of design/ construction drawing of properties in BIM-based format, when registering new 3D parcels (from design)?*

Question 3.15 *Are there any operational or in prototype stage platforms. implementations that reuse BIM information from design as cadastral/ land administration input?*

Question 5.8 *Are there any 3D City Model/ Digital Twin developments carried out at a national or city level that can be used for orientation or reference purposes?*

Question 6.10 *Are there object classes in the registration that require both real-world (or valid) times and database load (or system) times, i.e. bi-temporal support?*

3. PRELIMINARY ANALYSIS OF THE STATUS IN 2022 AND THE MAIN CHALLENGES FOR THE NEAR FUTURE

As mentioned, this paper presents an initial analysis of the responses from the thirty-seven (37) countries that participated in this survey, in order to present an overview of the main figures of the current status of LAS and the priorities and challenges for the near future (2026). Further analysis will follow at another publication.

At the table below, the statics regarding the number of 2D and 3D parcels per country/ jurisdiction, together with the size of the country and the current population are presented. It is noted, that for a few countries (i.e. Trinidad and Tobago) the number of parcels mentioned are not surveyed in total, while Croatia and the Netherlands also provided the area of their water territory. Lastly, there are some countries that provide figures for 3D parcels, that are usually grouped into volumetric parcels and building structures/ condominiums.

Table 2. *Statistics about the number of parcels from the participants (only the countries that provided data are presented)*

#	Countries reported the statistics of parcels	Size of county/ jurisdiction in sq km	Number of 2D parcels	Number of 3D parcels	Population (last data available)
1	Argentina	2.780.000	About 20 millions	0	47,4 millions
2	AUS - NSW	809.444	4.5 million	100.000+	8,1 millions
3	AUS – Queensland	1.730.648	2.252.878	3.069 (volumetric) & 274.095 (building format)	5.296.098
4	AUS – Victoria	-	-	-	-
5	AUS – Western Australia	2.642.753	1.1 million	479	2,8 millions
6	Bahrain	786,5	255.436 (including the		1.463 million

			2D parcels with 3D aspects)		
7	Brazil	8.510.345,538	-	-	207 million
8	Canada-Quebec	~ 1,7 millions	~3.900.000	~ 620.S000	8,7 millions
9	Croatia	56.594 land & 31.067 water	14.5 million	-	3,87 millions
10	Cyprus	9.252	~ 1.600.000	~162.000	~. 865.000
11	Czech Republic	78.866	22.712.065	0	10,52 millions
12	Finland (Case Espoo: & Case Tampere & Case Kajaani & Case Kuopio & Case Lempäälä)	6.182	738.000	171.390	16
13	Greece	131.944	~12.000.000	0	10,43 millions
14	Iceland	137.264	79.087	0	386.639
15	Montenegro	13.812	-	-	619.211
16	Nepal	-	31.895.591		29.136.808
17	New Zealand	268.021	2+ million	145.000+	~5 millions
18	Poland	312.680	38.102.232	0	37.827.000
19	Serbia	88.499	18.948.505	0	6.844.000
20	Singapore	721.5	1.7+ million	-	5,61 millions
21	South Korea	-	45 million	-	55 millions
22	Spain	505.990	53.097.474	~20.000.000	47.420.000
23	Sweden (Stockholm City & Gothenburg City & Malmö City)	808	165.130	492	1.918.068
24	Switzerland	41.285	4.000.000	~1.400.000	8.740.000
25	The Netherlands	33.883 land & 7.643 water	~ 9.000.000	~2	~ 17.500.000
26	Trinidad and Tobago	~ 5.000	~ 500,000	There are no official 3D parcels but there are many condominiums and apartments	~ 1.5 million
27	Turkey	784.000	58.7 million	-	84.7 millions

With regards to the responses received for the question 1.9. "*Is there legislation (law and/or regulations) for 3D descriptions of parcels?*", they are presented at the next figure. The majority responded that there is legal provision, while 14% declared that the third dimension is not explicitly introduced, but there are legal documents that partly or indirectly describe 3D parcels.

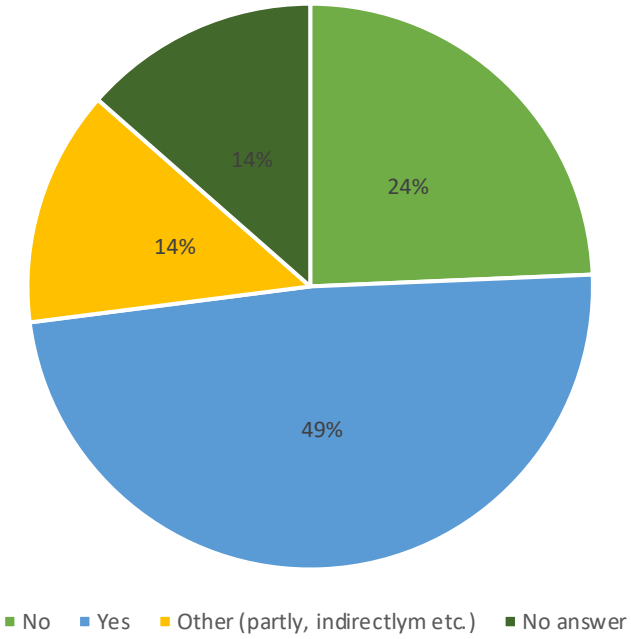

Figure 2. *Responses from participants regarding the existence of legislation for the description of 3D parcels*

From the new questions that have been introduced to the questionnaire, insights about the knowledge, familiarity and adaptation of ISO19152 LADM is gained, both for the current state of the LAS, but also regarding future provisions. At the following figure and paragra[h, the responses from the questions: 1.13. "*Is there a formal model for the 3D parcels (UML style); e.g. based on ISO TC211 series (especially LADM, ISO 19152)?*"; 1.23 "*Has there been developed any country profile based on LADM ISO19152?*" and 8.0. "*Is the database schema LADM based?*" are analysed and presented.

From the thirty-seven (37) countries that participated, only four (4) countries answered that ISO19152:2012 LADM is used as the formal model for the 3D parcels, the provincial city of Shenzhen in China, Finland, Malaysia and Scotland, while 35% of the total countries that participated, declared that their cadastral database is either fully or partially based on LADM.

As depicted at the figure below, almost have of the countries that have participated (49%) have not (yet) developed a country profile based on LADM. From those that have developed, a 41% declares that the country profile has either been developed at a preliminary stage (i.e. mapping between LADM classes and the respective LAS concepts), or it has been developed by academia and can be accessed through relevant publications.

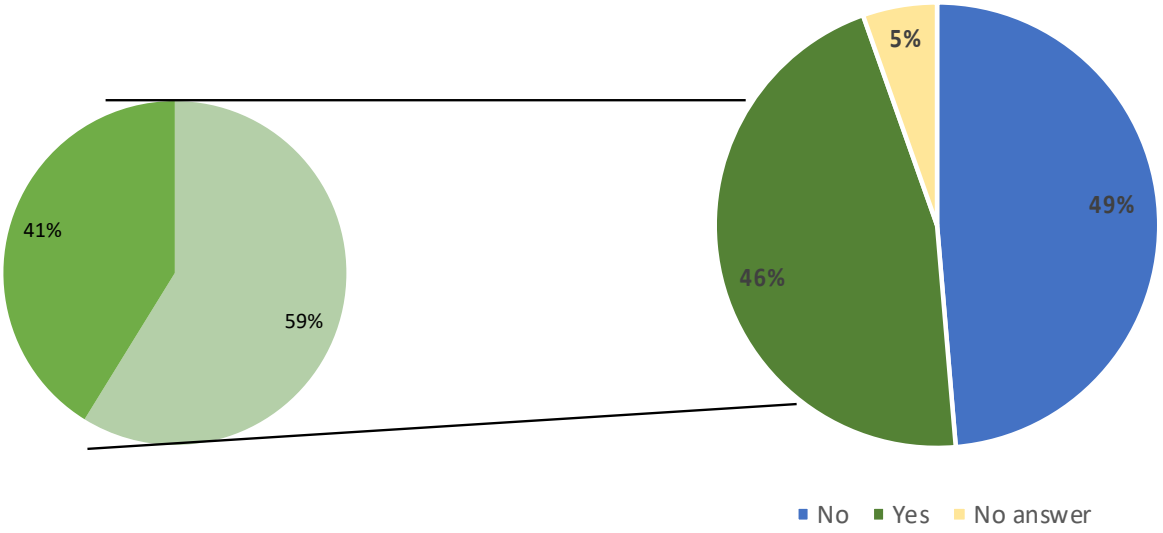

Figure 3. *Responses from participants regarding the development of ISO19152:2012 LADM- based country profile*

Finally, from Section 12, the priorities per country in the field of LAS for the next four (4) years, till 2026, have been collected and are listed in the following Table. The challenges reported by the participants can be categorised in the following three groups:

1. Legal aspects: specifically related to the provision of legislation that can support 3D in land administration
2. Organisation aspects related to capacity building on the personnel, in order to be able to handle a 3D LAS, the engagement of private sector and stakeholders, as well as the development of clear guidelines
3. Technical aspects: in terms of software development and interoperability between data and systems; usage of the latest technologies (VR, AR) and specific support for the 3D data capture, management and dissemination of the surveying-related information.
4.

Table 3. *Priority axes for the next four years related to the developments of 3D LAS, per (only the countries that provided data are presented)*

#	Countries reported their top priorities for 2026	Priorities axes
1	Argentina	▪ Concept of 3D parcel and 3D property development. ▪ Incorporate of a 3DGIS platforms on the cadastral institutions. ▪ Incorporate the LADM concepts at the public cadastral institutions.
2	AUS - NSW	▪ Data standards and interoperability ▪ Software capabilities / limitations ▪ Industry and stakeholder support for reform
3	AUS – Queensland	▪ Digital submission of surveying information.
4	AUS – Victoria	▪ Legal and cultural shift towards 3D digital environment. ▪ Technical issues such as 3D DCDB, visualisation (VR/AR), 3D Data Validation and Integrity ▪ Guidelines for 3D Data Capturing by Surveyors

		▪ Robust roadmap towards 3D land administration
5	Bahrain	▪ Cost and training ▪ Private sector to produce accurate As-Builts, ▪ Dissemination and data sharing
6	Canada-Quebec	▪ Providing spatial representation for any kind of overlapping properties, ▪ Having integrated strategy for immatriculated and not immatriculated real estate, ▪ Modernization of stakeholder practices (e.g. land surveyor, notary, etc) ▪ The evolution of laws and regulations
7	Croatia	▪ Capacity Building in LA ▪ New cadastral surveys ▪ Height and volume data capturing and maintenance
8	Cyprus	▪ Technical approach for data capture. ▪ Data model design. ▪ Cost of implementation.
9	Czech Republic	▪ The source of 3D data for 3D parcels (BIM could help) ▪ Visualization demonstrating the pros of having 3D parcels ▪ Legislation.
10	Finland	▪ There is a need for 3D right-of-use-unit
11	Kenya	▪ Formalization and development of LADM profile supporting 3D; ▪ Harmonization of the coordinate systems for cadastral data; ▪ Development of guidelines, besides the regulation on how to implement a digital 3D cadastre
12	Malaysia	▪ Data availability and legal aspect.
13	Montenegro	▪ The challenges are same as before. Even the researches about possible solutions are available, there is no enough understanding of the need for 3D cadastre.
14	Nepal	▪ Strong legal background ▪ Technical capabilities to acquire 3D information ▪ Visualization in cadastral information system
15	New Zealand	▪ Cost/effort associated with developing *Landonline* to handle 3D parcels digitally (as opposed to current aspatial 3D approaches coupled with 2D digital capabilities). ▪ Dependency on third-party software vendors to develop/extend applications to better support the creation and supply of 3D data for survey and title purposes. ▪ Need for support and guidance of surveyors/users during the transition to digital 3D.
16	Poland	▪ The law on the multilayer property must be enacted first.
17	Serbia	▪ Clear understanding of the need for 3D cadastre.
18	Singapore	▪ Legal aspect – to formalise certain legislations related to vertical dimension is time consuming; ▪ Mindset aspect – change management in both agency officers and surveyors to adopt 3D cadastres submission; ▪ Software – software developers should be fast enough to develop and support their software for 3D submissions.
19	South Korea	▪ Develop 3D cadastral law ▪ Demand society pressure

20	Sweden	▪ Standards as to 3D – GIS area for land administration. ▪ The role of BIM in the area, development is on-going. ▪ Capacity, resources, technical possibilities.
21	Switzerland	▪ Further adaptation of the legal basis and development of the data model of cadastral surveying (DCDB). ▪ Convince lawyers of the need to change the legal system to introduce a vertical limitation of a parcel. ▪ Education and training of professionals
22	The Netherlands	▪ Legal Framework (Civil Code) ▪ Technical Implementation and costs ▪ Maintenance
23	Trinidad and Tobago	▪ Systematic adjudication and titling, condominium legislation, ▪ Convincing the Government for the need and the benefits of 3D Cadastre ▪ Acquiring financial support for the development Capacity building of relevant personnel
24	Turkey	▪ Availability of 3D data ▪ Quality of cadastral data ▪ Legal difficulties

4. INITIAL CONCLUSIONS AND FUTURE STEPS

As several new countries participated in this questionnaire, while most of the countries that have participated in the previous questionnaires, still have the interest and contribute to this activity, it can be concluded that the interest on 3D Land Administration Systems worldwide is further growing. As this is the preliminary report of the 4th Questionnaire, further research and analysis will be conducted to analyse the responses of the participants per questionnaire section, identify the trends and priorities for the near future, as well as conclude to a comprehensive report, that can be also used from the participant countries, highlighting the good practices.

What is more, the responses related to the LADM, as presented at the previous section, will be compared and combined with the updated list of LADM-based country profiles, as it has been initially presented by Kalogianni et al. (2021). Finally, as an activity of the "3D Land Administration and Land Administration Domain Model" Working Group and within FIG Commission 7, the possible integration or combination of this periodic activity with the "Cadastral Template 2.0", an activity developed by a research group at the Centre for SDIs and Land administration, Department of Infrastructure Engineering of the University of Melbourne, which cooperates with FIG-Commission 7.

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BIOGRAPHICAL NOTES

Ing. Eftychia Kalogianni is a PhD candidate in the 'GIS Technology' Chair, Digital Technologies Section, Faculty of Architecture and the Built Environment, Delft University of Technology, the Netherlands. Her PhD research topic is about adopting a holistic approach to treat 3D Land Administration Systems within the spatial development chain, in the context of LADM ISO 19152 revision. She holds MSc in Geoinformatics from NTUA and MSc in Geomatics from TUDelft.

Prof. Dr. 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 database. Since 2000, he is Professor at Delft University of Technology, and head of the 'GIS Technology' Chair, Digital Technologies Section, 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' and co-editor of the International Standard for Land Administration Domain, ISO 19152.

Prof. Dr.-Ing. Christiaan Lemmen is full Professor Land Information Modelling at the Faculty of GeoInformation Science and Earth Observation of the University of Twente in the

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Prof. 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.

Dr. Rodney Thompson has been working in the spatial information field since 1985. He designed and led the implementation of the Queensland Digital Cadastral Data Base, and is now principal advisor in spatial databases. He obtained a PhD at the Delft University of Technology in December 2007.

Dr. Sudarshan Karki is a Senior Spatial Information Officer, Cadastral & Geodetic Data (Survey Information Processing Unit), in the Data Management & Acquisition, Spatial Information Group of Department of Environment and Resource Management, Queensland Government, Australia. He completed his professional Master Degree in Geo-informatics from ITC, The Netherlands in 2003 and is currently doing Master of Spatial Science by Research at the University of Southern Queensland.

Dr. Anna Shnaidman is the Chief Scientist at the Survey of Israel. She received her BSc, MSc and PhD degrees in Mapping and Geo-Information Engineering from Israeli Institute of Technology - Technion. Shnaidman is a Licensed Surveyor and a Lecturer as well. For the period of 2018-2020 she worked as a postdoctoral researcher and a Lecturer at the GIS Technology Section, Faculty of Architecture and the Built Environment, Delft University of Technology, the Netherlands – main research objective was the revision of Land Administration Domain Model (LADM - ISO 19152).

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