Analysis of the Third FIG 3D Cadastres Questionnaire: Status in 2018 and Expectations for 2022

Shnaidman, Anna; Oosterom, Peter van; Lemmen, Chrit; Ploeger, Hendrik; Karki, Sudarshan; Rahman, Alias Abdul

Publication date
2019

Document Version
Final published version

Published in
Proceedings FIG Working Week 2019

Citation (APA)
Shnaidman, A., Oosterom, P. V., Lemmen, C., Ploeger, H., Karki, S., & Rahman, A. A. (2019). Analysis of the Third FIG 3D Cadastres Questionnaire: Status in 2018 and Expectations for 2022. In *Proceedings FIG Working Week 2019 : Geospatial Information for a Smarter Life and Environmental Resilience* International Federation of Surveyors (FIG).

Analysis of the Third FIG 3D Cadastres Questionnaire: Status in 2018 and Expectations for 2022

Anna SHNAIDMAN, Peter VAN OOSTEROM,
Christiaan LEMMEN and Hendrik PLOEGER, the Netherlands
Sudarshan KARKI, Australia and
Alias ABDUL RAHMAN, Malaysia

Key words: Cadastre, Digital Cadastre, 3D Cadastres, Questionnaire, Worldwide Survey, Land Administration

SUMMARY

The 3rd FIG 3D-Cadastres Questionnaire was conducted and distributed by the end of 2018, with an extended deadline of 15th of January 2019. The questionnaire survey is a part of the FIG working group 3D-Cadastres activities for the period of 2018-2022.

The purpose of this survey is to prepare a comprehensive inventory of the current (2018) state of 3D Cadastres worldwide, to explore the near future (2022) plans and expectations in the field and to evaluate the progress during the past four years. Sharing and dissemination of this information, enable to improve cooperation, to learn from each other and to support future developments as well as to encourage collaboration between various countries and jurisdictions.

As can be determined from the title, this is the third time that the questionnaire on 3D-Cadastres is being carried out. The first version was administered in 2010 in order to document the status of 2010 3D Cadastres and of the then upcoming 2014 expectations. This was followed by a second questionnaire in 2014 (with status of 2014 and ambitions for 2018). The previous responses (van Oosterom et al., 2011; van Oosterom et al., 2014) were analyzed and reported at earlier FIG events (Working Weeks and workshops).

The structure of the 3rd questionnaire has remained rather similar. All of the sections and the numbering of the questions were preserved to allow straightforward comparison with the earlier questionnaires and identification of potential trends. A few questions have been refined for clarification and several new questions have been added at the end of the sections. In this paper the main results of the analysis of the submitted 2018-2022 questionnaire are presented together with an analogy drawn between the past and present responses.

Analysis of the Third FIG 3D Cadastres Questionnaire: Status in 2018 and Expectations for 2022

Anna SHNAIDMAN, Peter VAN OOSTEROM,
Christiaan LEMMEN and Hendrik PLOEGER, the Netherlands
Sudarshan KARKI, Australia and
Alias ABDUL RAHMAN, Malaysia

1. INTRODUCTION

Over the past few decades, due to accelerated pace of living, urbanization and various economic alongside social and political factors, land has become a scare commodity. Thus, more and more countries are exploring the potential of construction below the surface. Furthermore, contemporary architecture and the way the aboveground as well as subterranean spaces are being utilized, driven by numerous societal needs, are vastly evolving and becoming too complex for the existing land administration systems to handle, as illustrated in *Figure 1*. In addition, the vast application possibilities of an operational 3D system - which include: smart cities, sustainable 3D land use, solutions for subsurface infrastructures, natural resources management - are in line with the sustainable development goals and global trends, thus enhancing the importance of the subject.

Figure 1: Complex Constructions – Examples from Around the World *(Keat Lim et al., 2018)*

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 thereof: *People*, *Space* and *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 are 2D based and unable to accommodate the variety of complex situations impelled by the reality of the modern world. In particular, proper registration and security of overlapping horizontal rights or vertical partition of the space. As a result, 3D Cadastres and consequently 3D-based land administration systems, have been the subject of much research and debate (Lemmen et al., 2003; van Oosterom, 2013; van Oosterom et al., 2018) 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*.

One of the initiatives carried out by the working group in pursuit of realization of the working group objectives[1] (van Oosterom et al., 2011) is the 3D Cadastres Questionnaire. Which is a comprehensive survey encompassing the entire spectrum of 3D Cadastres, both from legal and spatial/technical perspectives. Seeing that each country may have its own definitions of land related concepts, LADM terminology is used to create a common language. The goal of this worldwide inquiry is to recurrently examine the status of the 3D Cadastres activity at a certain moment (the questionnaire is being issued every four years starting 2010), monitor the progress and to assess the future expectations and strategies.

All the members of the 3D Cadastres working group, including leading experts in the filed coming from academia as well as from the industry and governmental institutions, have been requested to complete the questionnaire for the 3rd time. *Table 1* presents the years of participation, the number of participants and the corresponding countries. In addition, the complete questionnaires are available on the working group website[2].

There were **36** submissions in **2010**, **33** completed questionnaires in **2014**, currently **28** surveys were received and a few more including: New Zealand, Australia New South Wales, Indonesia and Costa Rica are expected in the near future. The surveys, once available, will be uploaded to the 3D Cadastres website, under "*participants*" section (see footnote 2) and included in the presentation at the FIG Working Week 2019.

In total **22** countries/jurisdictions completed the questionnaire for all years: *2010-2014, 2014-2018* and *2018-2022*. There was only one new participant in 2018 - Scotland; and there were no countries which submitted their survey only in 2010 and 2018. *Table 1* summarizes key statics of the submitted surveys. The years, number of participants and the list of countries are presented accordingly. Some of the countries that didn't take part in the latest survey, attributed it to the fact that there were insignificant changes - if at all, in comparison with previous questionnaire.

[1] http://www.gdmc.nl/3dcadastres/objectives/

[2] http://www.gdmc.nl/3dcadastres/participants/

The remainder of the paper is structured as follows: a short overview of the questionnaire is given in Section 2; Section 3 summarizes the current state of the 3D Cadastre based on the received questionnaires; in Section 4 the highlights of the progress in 3D Cadastre domain over the past few years are reviewed; and finally section 5 presents concussion remarks and future aspects.

Table 1: Completed questionnaires, years: 2010, 2014, 2018

<table>
<tr><th colspan="3">Questionnaire completed in</th><th>Number of Participants</th><th>Countries/Jurisdictions</th></tr>
<tr><td colspan="3">All years: 2010/2014/2018</td><td rowspan="3">22</td><td rowspan="3">Argentina, Australia/Queensland, Canada/Quebec, China, Cyprus, Finland, Germany, Greece, Hungary, India, Israel, Kenya, Malaysia, The Netherlands, Nigeria, Poland, South Korea, Spain, Sweden, Switzerland, Trinidad and Tobago, Turkey</td></tr>
<tr><td>2018</td><td>2014</td><td>2010</td></tr>
<tr><td>√</td><td>√</td><td>√</td></tr>
<tr><td colspan="3">New Participants: 2018</td><td rowspan="3">1</td><td rowspan="3">UK - Scotland</td></tr>
<tr><td>2018</td><td>2014</td><td>2010</td></tr>
<tr><td>√</td><td>-</td><td>-</td></tr>
<tr><td colspan="3">Previous years participants: 2018/2014</td><td rowspan="3">5</td><td rowspan="3">Croatia, Czech Republic, Portugal, Serbia, Singapore</td></tr>
<tr><td>2018</td><td>2014</td><td>2010</td></tr>
<tr><td>√</td><td>√</td><td>-</td></tr>
<tr><td colspan="3">Previous years participants: 2018/2010</td><td rowspan="3">0</td><td rowspan="3">-</td></tr>
<tr><td>2018</td><td>2014</td><td>2010</td></tr>
<tr><td>√</td><td>-</td><td>√</td></tr>
<tr><td colspan="3">Previous years participants: 2014/2010</td><td rowspan="3">5</td><td rowspan="3">Australia/Victoria, Brazil, Denmark, Macedonia, Norway</td></tr>
<tr><td>2018</td><td>2014</td><td>2010</td></tr>
<tr><td>-</td><td>√</td><td>√</td></tr>
<tr><td colspan="3">Previous years participants: only 2014</td><td rowspan="3">1</td><td rowspan="3">Costa Rica</td></tr>
<tr><td>2018</td><td>2014</td><td>2010</td></tr>
<tr><td>-</td><td>√</td><td>-</td></tr>
<tr><td colspan="3">Previous years participants: only 2010</td><td rowspan="3">9</td><td rowspan="3">Austria, Bahrain, France, Indonesia, Italy, Kazakhstan, Nepal,
Russia, UK - England & Wales</td></tr>
<tr><td>2018</td><td>2014</td><td>2010</td></tr>
<tr><td>-</td><td>-</td><td>√</td></tr>
</table>

2. QUESTIONNAIRE'S LAYOUT AND DESIGHN

As previously stated, the questionnaire aims at addressing every aspect concerning 3D Cadastre domain. Seeing that in a four-year time interval between the surveys, there are constant technological developments along with changes in other respects, revision and updating of the

questionnaire is in order. Hence, a few questions were added. *Table 2* details the newly included questions.

Table 2: New Questions

1.17. *Is there a Marine Cadastre? And if so, are 3D parcels included in this registration. Is the IHO Maritime Limits and Boundaries standard (S121) in use or under implementation?*
1.18. *Is there any organized legal instrument for the management of common property?*
1.19. *Which agency is responsible for the recording of titles information?*
1.20. *Which agency is responsible for recording cadastral transactions?*
1.21. *Are transactions for standard 2D lots and 3D lots done by the same agency or titles office?*
1.22. *Are there any 3D storage permissions recorded (e.g. underground storage of CO2)?*
4.6. *When owners receive or purchase a copy of the plan what can they see on the plan to help them identify their parcel/lot (e.g. bearings and distance, identifying corners or recovery marks, neighbouring lots, coordinates etc.)?*
4.7. *Were there any changes made in the way cadastral information is recorded and represented from a historical point of view?*
5.6. *How is elevation information recorded in the cadastral plan or database?*
5.7. *Do you expect the elevation recorded in cadastral plans to be used for any other purpose (e.g. city models or civil constructions etc.)?*
6.6. *In case 3D Marine Cadastre is present and moving boundaries are allowed, how is this represented? E.g. using 4D geometry and topology.*
6.7. *Can time bound rights be created and extinguished in the title? (e.g. temporary titles created for a period and when the time is up it can be extinguished)?*
6.8. *Is it possible to identify all the changes made by any operator to the cadastral plans or database and to rollback if there is an error made?*
6.9. *For Cadastral transactions, how far in time do buyers need to make a search to ensure the title or deed is legal?*
7.13. *Is the 3D registry separate or integrated with the 2D registry?*
9.19. *Do the cadastral survey plans differentiate between different types (e.g. volumetric plans, building plans and standard 2D plans)?*
9.20. *What are the usual elements shown on the plan (e.g. North Arrow, Marks table, Observation table, Administrative data, Plan face and dimensions etc.?)*
9.21. *Are authoritative cadastral surveys carried out by government surveyors or private licensed surveyors or both?*
9.22. *What is the legal description of a cadastral boundary (e.g. coordinates or bearing and distance or lines on plan or any other)?*
9.23. *How much time does it usually take for a subdivision process to be completed?*
9.24. *What is the legal source for cadastral representation (e.g. cadastral plans, or Digital Cadastre Database – DCDB or index plans or descriptive sketch/text etc.?)*
9.25. *What is the positional accuracy of the cadastral plans (e.g. boundaries may be accurate but may not be referenced in datum properly)?*
12.5. *In case of not yet fully operational status, were there any 3D Cadastre registration pilots to take steps towards a fuller implementation?*

12.6. *In case of known legal barriers, have there been made progress in creating and adopting new legislation to support 3D land administration?*

Currently the survey comprises 13 sections in total. The first ten sections focus on more technical and practical characteristics, such as: (1) 3D real-world situations, geometry, 3D representation; (2) underground utility cadastre; (3) condominium/3D property registration; (4,5) geodetic infrastructure; (6) temporal issues; (7) legal aspects and legislation; (8) databases and (9) survey plans. The remaining three sections are more of a supportive information nature concerning (10) data dissemination, (11) statistics and (12) reflection including the (13) contact details of the participants[3].

Altogether 24 new questions were added. Primarily section 1 - 6 new questions pertaining to marine cadastre, common property management, the organizations responsible for title and transactions registration and the recording of designated 3D storages; section 9 - 7 additional questions were included mainly referring to cadastral plans features and their functionalities.

The time related issues are gaining more and more attention as well, 4 new questions were devised. 4D geometry and topology and their legal ramifications were further addressed.

In general, the layout of the questionnaire is consistent with previous versions. The added questions are following the numbering established in the previous surveys. This practice allows easy navigation within the document for those who completed the questionnaire before and facilitates the comparison process.

3. INITIAL ANALYSIS OF THE 2018 3D CADASTRES STATUS

The analysis of the responses received to the third 3D Cadastres questionnaire, which reflects the status of the 3D Cadastres worldwide, is thereby presented. The findings are organized in correspondence to the first 11 sections of the survey.

3.1 General/Applicable 3D Real-world Situations

Since the majority of participating countries do have an operational 2D cadastre, the first question is whether or not the 3D units are or should be bound by the existing surface parcels. There is no particular answer though there is a tendency toward a "YES". Poland and Czech Republic refrained from answering due to the absence of a legal 3D parcel.

In the case of ambulatory boundaries, in some countries the 2D representation is permitted (e.g. Germany), both riparian and littoral lines are mentioned. In Australia Queensland 3D moving boundary is allowed as well. In Canada 3D ambulatory boundaries exist only in theory. Countries such as: China, Croatia, Cyprus, Czech, Finland, Israel, Malaysia, Poland, Serbia, Spain and Sweden operate within fixed boundaries.

In some countries the 3D parcels are connected to physical objects, usually condominiums. In others, the common practice is referencing to physical objects, however not restricted by it, for example: Canada. Some countries such as: Greece, India (governmental minerals rights),

[3] For more elaborate description, please refer to ***2 previous reports*** and the 2018 questionnaire (http://www.gdmc.nl/3dcadastres/participants/3D_Cadastres_questionnaire2018.pdf)

Kenya, Malaysia (subsurface legal spaces), Portugal (primarily underground water bodies), South Korea allow not physical-object-related 3D units in particular cases. And there are countries that didn't specify any conditions for 3D legal spaces: China, Croatia, Finland, Singapore, Australia Queensland, Israel and Scotland. Almost none of the respondents indicated the potential ratio between related and nonrelated to physical objects volumetric units, besides Australia Queensland - more than 60%, Canada estimates a possible 5% or less.

Whether 3D parcel may consist of multiple parts or should portray one single connected space, is another issue with many diverse answers. The following countries support a connected parcel: Argentina, Canada, China, Finland, Israel, The Netherlands, Hungary, Nigeria, Poland, Serbia, South Korea, Spain and Turkey; whereas these advocate for a multipart approach: Australia Queensland, Croatia, Cyprus, Greece (mainly in condominium), Kenya (true for 2D, potentially refers to 3D as well), Malaysia (typically strata parcels as car parks), Portugal, Sweden and Scotland. In some cases, an apartment along with its accessory unit/s (for instance parking lot, storage room etc.) is perceived as one multi-part parcel. This alternative is considered to be addressed via designated question in the future questionnaires.

It's worth mentioning that the discord in replies might stem from interpretation of the questions as can be concluded from a comment by Chinese representative who states that from their perspective a single 3D parcel cannot be disconnected and should depict a solid volume. It should be noted that ISO 19152 standard does allow for individual, both 2 and 3 dimensional parts to form a single parcel.

The geometry restrictions vary, some countries such as Australia Queensland and Sweden are more strict – all 3D parcels must have closed volumes, some require spatial limitation with regard to certain units or/and only to above or below surface space, for instance: public water bodies (Argentina), 3D urban areas units (Greece). Curved surfaces are allowed in some countries, Australia Queensland, Canada, and Israel don't have any geometrical constraints, and few rely upon mathematically defined surfaces or bound by horizontal surfaces.

Quite a few countries have relevant legislation in form of law, regulations or similar to Canada, guidelines for cadastral plan production. In most of the countries the registration of buildings is regulated by law (variations of condominium or strata title laws), however the property itself usually not represented or stored in 3D. No country has reported having an explicit prototype, beside Singapore, however, a 3D survey plan is operational in Australia Queensland; in Greece Special Real Property Objects (SRPOs), such as: condominiums are considered operational 3D units; in the Netherlands, for the depiction of 3D parcels, the deed may contain a 3D PDF. A prototype that was developed in academia is presented by Israel, in addition Cypress has a model for apartments and Canada suggested a procedure for 3D representation of vertical limits of a property via complementary plan (PC). The cadastral plan contains a reference to the corresponding PC (Pouliot et al., 2010).

A number of countries integrate the natural resources into their land administration systems, though in most cases only certain resources are presented and rarely as 3D parcels. Furthermore, a remark was made, by an Australian (Queensland) participant, as to the ambiguity of the concept of land administration and whether the term refers to digital cadastre or to the land tenure system.

One of the new topics addressed by the questionnaire is the marine cadastre. Only a handful of countries have a designated system for maritime mainly in 2D, among them: Australia Queensland, China, Malaysia, Portugal and Scotland. Other reported registry of marine activities - Cyprus, registration on marine parcels as part of land cadastre – Israel and marine cadastre as part of oil exploration enterprise in Nigeria and Trinidad and Tobago.

Several more recent questions refer to: (a) common property - several countries indicated administering a specific legislation enabling the management thereof; (b) agencies responsible for title and cadastral transaction recording – commonly the land registries authorities are responsible for the rights registration and Cadastre authorities in charge of the transaction part. In some cases the same governmental body is liable for both; (c) records of 3D storage permissions (e.g. CO2 underground storage facility) - the majority either left this answer slot blank or replied "NO", with the exception of the Netherlands, where such permissions are recorded as a part of a separate key registration for subsurface ("*the Dutch Key Register of the Subsurface*"). Portugal and Cyprus replied positively, Switzerland is exploring the prospect via ongoing studies, and Nigeria specified recording of fuel and gas storages facilities.

3.2 Infrastructure/Utility Networks

One of the latest topics being discussed at recent professionals gathering is the utility cadastre. In this context the questions are associated with the legal space and the corresponding RRRs. Following are some exemplar questions. *Are infrastructures (above surface and subsurface) part of the land administration? Are they being recorded, represented on maps and handled as unique entities?*

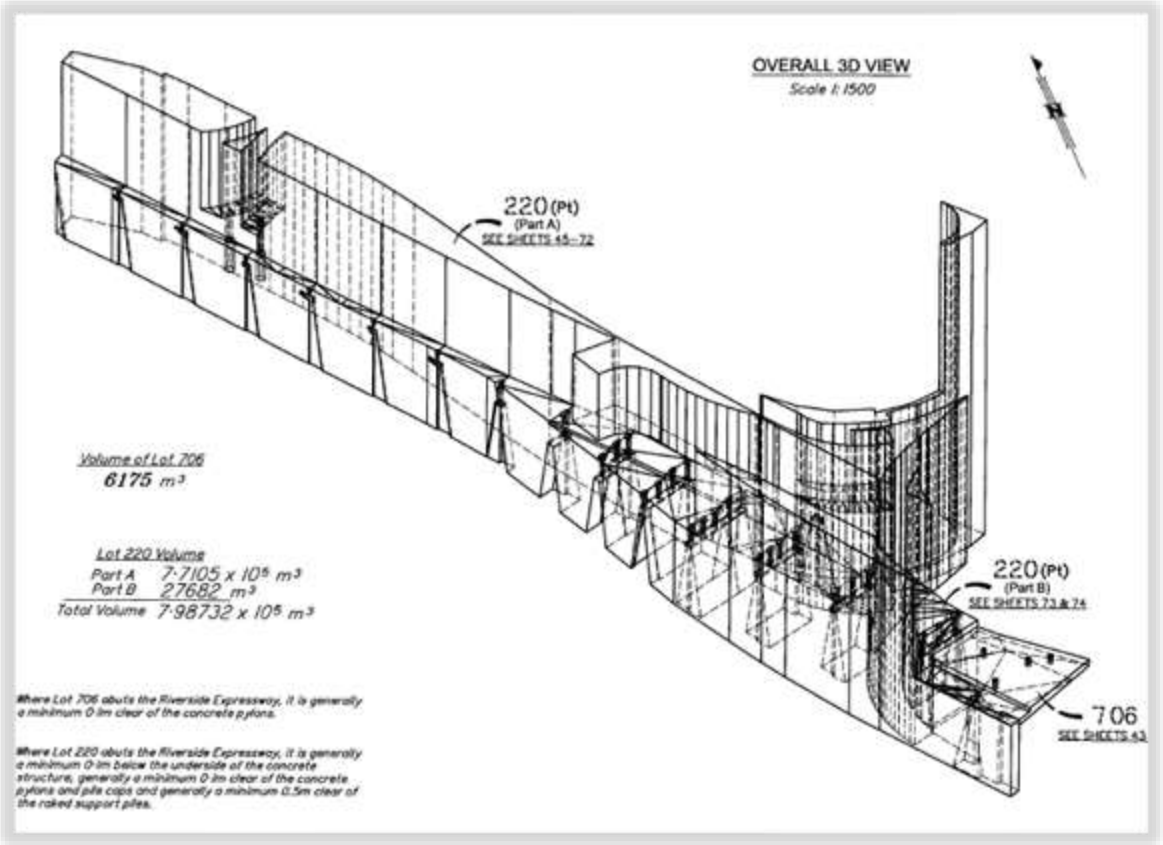

Figure 2: Isometric View of a Volumetric Lot in Queensland, Australia

Most countries do not define infrastructure network within the land administration, with the exception of: Australia Queensland where the infrastructure are registered as individual spatial units (*Figure 2* above); Argentina - in some cases; the Netherlands - the outline of the networks is depicted in 2D on a cadastral map; Canada – particular networks; Sweden - including is graphical representation as well as unique cadastral identifier; Switzerland - partial registration and Scotland. Special cases are Croatia and Serbia which have a designated utility cadastre. Some countries have private networks regulated but law, others don't. Whether or not there utilities are depicted on a map, the representation is in 2D and in times merely an approximate one.

3.3 Construction/Building Units

As can be expected the dominant building unit indicated by the respondents is an apartment. Most of the countries have specific laws which regulate the way a building is being registered, how the boundaries are defined (typically middle of the wall/floor/ceiling or according to the inner outline of the unit) and who owns the common property (in general, by all apartments owners according to a set percentage/share). Furthermore, several countries allow commercial as well as residential and industrial units to be registered, including different types of units: parking garages, storage units, shops, offices, underground cellars (e.g. Hungary). In China bridges and over-street buildings are also subject of registration.

3.4 X/Y Coordinates

According to the questionnaire, most of the countries employ an absolute spatial reference system for the planimetric coordinates, to name a few: China, Croatia, Germany, Hungary, Portugal, Spain, Switzerland, Singapore and Israel. However, some may use relative or local system, for example: Argentina, even though parcels must be georeferenced by law. Several countries, among them: Sweden, use both the absolute and relative systems. It is interesting to mention that several countries utilize more than one reference system: Israel, Canada, Kenya, Poland, the Netherlands and Serbia. The survey plan may provide X/Y coordinates in some cases, the answer vary. Regarding the authority of coordinates stored in a cadastral database, some countries gave a firm "YES", others indicate some constraints or indicate that the values are merely informative - Sweden. In Cyprus for instance, coordinates of the new plans have legal bearing, it is not the case for old plans. Israel, has a coordinate classification procedure, based on accuracy, measurement method and available original data. Conforming to the findings of the aforementioned procedure, coordinates with a certain classification are authoritative. Czech Republic allows two sets of coordinates: authoritative originated in geodetic measurements and informative values.

With respect to boundaries being defined by building contour rather than by coordinates, Australia Queensland, Canada, Nigeria, Scotland, Trinidad and Tobago (old surveys), Sweden, Switzerland (only very few), Spain, Germany, Hungary, Serbia, Czech Republic, Malaysia, Portugal, the Netherlands (but with recorded geometry) Israel (old field sheets) and Greece indicate this as an existing practice.

There quite a few recurring elements depicted on the cadastral plan as noted by the participants: bearing and distances, corners, usually neighboring lots, some use a unique identifier - Greece, Hungary, Israel and Serbia. Canadian plans similar to ones in Israel also contain area values. In Croatia solely adjacent parcels are shown. Land use contours are presented on plans in Poland, color coded overlaying rights are supported by plans in Scotland, whereas in Sweden both RRRs and main building details can be found on the plan.

From a historical point of view a few countries reported changes in reference systems/datum - Malaysia, Nigeria, Portugal and Switzerland; new regulations, mainly concerning electronic submission of parcellation plans and the format of the plan, came into effect in Israel; in Australia Queensland the units were changed as well as the legislation; Poland made a transformation to a digital cadastre. Map based registration was enabled in Scotland. In Singapore, the way the cadastral information is being represented has undergone several modifications: from hardcopy to a digital scanned copy and finally to a LandXML format.

3.5 Representation of 3rd Dimension: Height (or Depth)

As for the third dimension representation, several countries use absolute values reduced to a standard datum: Australia Queensland, Canada, Finland, China, Israel, Poland, Turkey, Switzerland and Portugal; other favor local ground heights, for example: Australia Queensland, Malaysia, Trinidad and Tobago, Serbia, Spain, Scotland and Kenya. Greece utilizes both relative and absolute heights.

One of the new questions deals with the way the elevation is being recorded. Not many countries encompass Z values in cadastral plans as they are still 2D-based, some exceptions are: Malaysia,

Greece, China and Australia Queensland where relative height differences are depicted in 3D plans. Six of the participating countries store the height in cadastral databases – Turkey, Finland, Spain, Switzerland, Singapore and China. Some countries currently prefer other ways such as: contour lines, DEM, DSM and/or DTM models – Cyprus, Israel, Czech Republic, Greece and Nigeria.

Almost all participating countries intend to make use of the elevation data for other purposes, though not elaborating which. 3D City models were mentioned by Greece and Singapore, Portugal expects civil construction to benefit from the height component data much similar to Switzerland. It is important to note that the question is referring to data recorded in cadastral plans, however in most cases, the height component is not part of the cadastral plan and the potential utilization of the 3rd dimension for alternative uses is mentioned by the countries in general.

3.6 Temporal Issues

The time dimension mainly manifests in temporal titles, which records time-limited rights. This is an applicable practice in: China, Cyprus, Kenya, Portugal and in Scotland. These category of titles primarily deal with different types of leases or individual situations: Canada - Emphyteutic Lease, Greece Israel and the Netherlands - long term leases, Nigeria, Malaysia - private lease, Czech Republic - right of building (special case), Australia Queensland - some cases of volumetric parcels for specific purposes are registered, Poland - perpetual usufruct and the Netherlands.

Only 8 countries include temporal limits as part of their parcel definition, for example: Argentina, Australia Queensland - secondary interests such as leases have temporal aspects, China, Kenya, Nigeria, Portugal, Spain and Malaysia for leases. Even fewer, allow moving boundaries, including: Argentina, Australia Queensland (grazing and mining have moving leases), Greece, Spain, Scotland and the Netherlands (a unique phenomenon of floating parcels, usually houses, on water).

The vast majority of countries indicated that it is feasible to identify the changes made in cadastral plans and/or databases and rollback in case an error was made.

The inquiry time period needed in order to ensure title/deed validity for cadastral transaction, varies among countries. In some, current title is valid as per definition of Torrens registration system (Croatia, Cyprus, Finland, Hungary, Serbia, Sweden and Turkey), others require different periods of time starting at 7 days (Kenya), 30 days (Czech Republic), weeks or months (Nigeria) and ending with 20 yeas (Trinidad and Tobago) and 30 years (Greece).

3.7 Rights, Restrictions and Responsibilities

At present, the focus of 3D registration of rights, restrictions and responsibilities (RRRs) lies on condominiums, where the responsible party for recording these RRRs is usually the Land Registry agency. For the most part the only limitation on the rights is in case of mines (minerals etc.) or antiquities (Greece, Israel). In Switzerland on the other hand, the deep subterranean space is owned by Government as stipulated by law, however there are no actual 3D parcels delimitating the boundaries. Similar situation occurs in Singapore, space below 30 meters depth belongs to the Government.

The lion's share of the countries have adopted the title-based registration system, nevertheless some, similar to the Netherlands, operate the deed system and few others still rely upon both, e.g.: Czech Republic, Scotland, Greece (in transition to title), Israel and Sweden (mainly title), Poland and Trinidad and Tobago (largely deed).

Based on the answers, most of the foreseeable application for 3D land administration pertain to urban planning and management. Other benefits noticed are: property valuation and taxation (Croatia and Canada respectively), decision making and energy consumption assistance (Greece) to name a few.

To the question whether the 3D registry is/expected to be an autonomous one or is integrated within the existing 2D system, most of the countries beside Kenya advocate for unified system, and several clearly stated there is no operational 3D registry just yet (Argentina, Greece, Spain).

Furthermore, it is expected for the same organizations to handle 3D land administration related, both legal and spatial issues, such as: boundary accuracy and the registration itself.

3.8 DCDB (The Cadastral Database)

In view of technological innovation and shift to digital form of communication, one of the topics the survey directs attention to is cadastral database and the implemented procedures involving storing and querying of 3D data and standardization of the database schema (i.e. LADM-based).

Judging by participating countries responses, this matter requires further investigation and development. Hardly any country's DB enables to store 3D geometry, representation of 3D parcels is typically achieved by means of textual and projection descriptions.

China is leading with 3D building plans models, spatial and topological query support and several GIS/CAD software (ArcGIS, Skyline, SketchUp) at their disposal. Both China and Singapore reported having an LADM-based database schema. Also, the future 3D system of the Netherlands is expected to be fully compliant with the LADM ISO standard. Few other countries reporting being partially aligned with LADM, for example: Croatia, Czech Republic, Finland, Germany Malaysia and Portugal.

Another country that is showing progress is Finland: DB allows 3D parcel representation via CityGML-Model, it is possible to store geometry and manage topological structure in the DCDB in addition to performing vertical query on the neighboring parcels.

In general, the object - oriented and the multilayer approach for database organization is applicable; commercial (ArcGIS), open data (QGIS) and self-developed software are used for data visualization and editing.

3.9 Plans of Survey (including field sketches)

The analysis of this section focuses on the new 7 questions that were added to the survey, covering the following aspects: are there different types of cadastral survey plans, elements featuring on a plan, responsible party for carrying out an authoritative survey, legal description of cadastral boundary, timeframe for a subdivision process to be completed, legal source for cadastral representation and positional accuracy of the boundaries depicted by the plans.

The most frequently occurring elements on a plan are: north arrow, plan title, boundaries of the parcel, buildings outline, reference marks, plan face, surveyor info, scale, administrative information, parcel number, signatures and neighboring lots. In Greece also administrative boundaries (municipal, district's boundaries and so on) are shown. The elevation is one of the features in Canadian plan. It is worth mentioning that some countries have different types of cadastral survey, for instance in Australia Queensland there are 3 formats, and other jurisdictions only keep one.

Authoritative surveys are generally carried out by both licensed private and governmental surveyors. In some countries the surveys performed by private surveyors are being verified by governmental representatives. Finland and the Netherlands reported employing solely public professionals.

Most countries use distances and angles for the legal description of cadastral boundaries, others utilize coordinates, for instance: Cyprus, Czech Republic, Finland, Hungary, Greece, Turkey, Singapore and Israel (in some cases). Malaysia reported regulating requirements for 3D survey plan, presently for underground parcels alone. *Figure 3* below, presents a certified stratum plan for a subsurface unit, which is prepared based on "as maid" surveys (Rajabifard et. al, 2018).

The time needed to complete a subdivision ranges from: 30 days – Canada, Hungary, couple of weeks – Argentina, to a few months – Australia Queensland, Cyprus and Czech Republic. Some countries have less specific timeframe that depends on involved parties and the restriction within the area, like in the case of Greece and Israel where the process may be prolong to several years due to legal complications.

Regarding the legal source for cadastral boundaries representation, some participants: China, Serbia, Hungary, Singapore, South Korea and Spain indicated cadastral databases as the source, others: Czech, Malaysia, Portugal, Turkey and Switzerland, mentioned cadastral plans. However, several countries interpreted the question in much broader terms and quoted specific regulations.

The geometry in most cases is portrayed correctly, the referencing accuracy ranges from millimeters (Singapore) and centimeters (Australia Queensland, Hungary) to meters (Nigeria – 5 [m]). At times the accuracy is scale depended or correlate to the precision of the observation method.

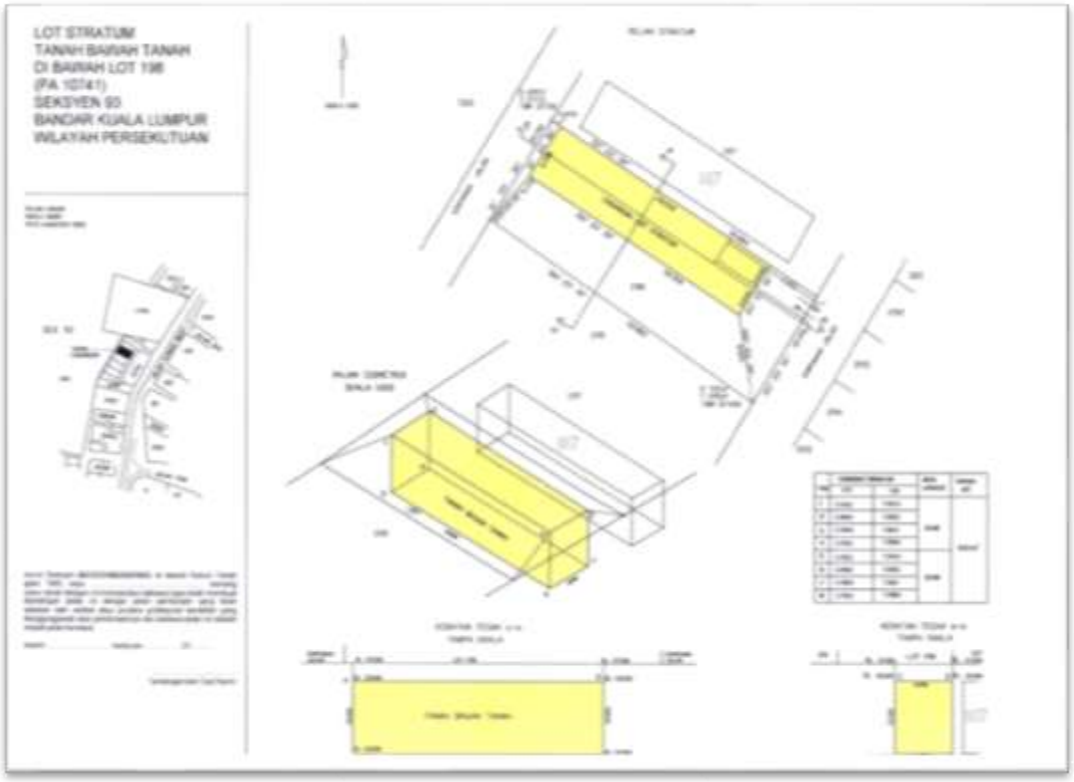

Figure 3: A Certified Stratum Plan – Malaysia

3.10 Dissemination of 3D Cadastral Information

Over the past few years more and more governments endorse the transparency[4] and data accessibility policy, thus cadastral data dissemination practices is an important issue. The majority of the participants in the survey indicated exploiting web-based systems (e.g. portals) for general public use or for professionals alone. However, in nearly all countries the geoportal does not include 3D data, with the exception of: China, Finland, Croatia - 3D data is combined as text, Cyprus - DTM and contours, Spain - buildings are presented in 3D (*Figure 4*), Germany - building are shown in perspective view in LoD[5] 1 and LoD 2, Sweden - 3D Property and Switzerland - solely the canton of Geneva is in 3D and the data is not available to general public.

Furthermore, it appears that integrated data portals are not common, i.e. legal information is not accessible via cadastral data dissemination source. Nevertheless, gradually more countries engage in providing integrated data, following are a few examples: Australia Queensland, China, Spain, Germany, Canada - titles and deeds provide an incomplete RRRs overview, Croatia, Cyprus, Finland, Greece - the legal information has a restricted access and available only to professionals, and Sweden.

[4] http://blogs.worldbank.org/governance/land-transparency-what-makes-good-initiative-case-responsible-investment-index

[5] Level of Detail

Figure 4: Geoportal and the Corresponding KML File with 3D Building Model - Spain

3.11 Statistical Information

According to the statistical data provided by the participants, only very small number of jurisdictions practice volumetric parcel registration, among them: China and Australia Queensland. Virtually all countries record either buildings/apartments or units with 3D aspects, for example SRPOs and mines in Greece.

There was no particular rule or value reported for the minimal/maximal size of a three dimensional parcel, yet, several countries did mention urban planning regulation, usually with respect to 2D parcel, as a rule of thumb and the size or real-world objects, such as tunnels. As anticipated, in relation to rural vs. urban areas 3D parcels ratio, the balance is clearly in the favor of the latter.

Judging by the wide variety of answers, especially with reference to the answers given in section 3 - "*Construction/Building Units*" of the questionnaire, there is a misconception regarding what constitutes as 3D parcel. In most countries, apartments as well as a few other types of volumetric units, conceptually considered to be a 3D object. However, they are not registered or stored as such. The third dimension might manifest in textual descriptions, 2D footprints or in more advanced cases as 3D models or in 3D PDF files.

Israel, Germany, Hungary, Portugal, Serbia, Singapore, Scotland and Czech Republic view 3D parcels as generic volumetric entities, defined in space and not merely as a specific case of apartment registration (the listed countries reporting not having 3D registered parcels even though answering affirmatively to the questions of section 3 – registration of condominiums).

4. REFLECTION, PROGRESS HIGHLIGHTS AND 2022 EXPECTATIONS

As previously mentioned, one of the goals of the survey is to observe the advancements which have occurred during the 4-year time period. As can be concluded from the previous questionnaires, the obstacles on the way to fully operational 3D Cadastre, were lying within the field of either legislation - lack of proper regulations or limitations dictated by laws or technological and organizational impediments. Since cutting edge technology constantly emerges, and new acts are being proposed, it is interesting to review whether these innovations

were applied, the expectations answered, which issues were resolved and what are the challenges to be faced ahead.

4.1 Reflection

Following are the fundamental issues to be addressed to promote the progress of 3D land administration:

- ***Argentina*** - development of the 3D parcel and property concept; incorporation of 3D GIS platforms within cadastral institutions; adopting LADM at academic level
- ***Australia Queensland*** - 3D ePlan submission; Validation; Storage mechanism
- ***Canada Quebec*** - representation of networks and various objects such as windmills
- ***China*** - official organization
- ***Croatia*** - land policy; real property taxation; legal uncertainty resolution
- ***Cyprus*** - technical approach for data capture; data model design; cost of implementation
- ***Czech Republic*** - data source for 3D data (use of BIM[6] for cadastral purposes); visualization issues; legislation issues
- ***Hungary*** - Surveying guidelines, standards for 3D legal spaces; legal issues; visualization of 3D rights
- ***Malaysia*** - legislation; collaboration between agencies; 3D database structure
- ***The Netherlands*** - A feasible and financially applicable solution
- ***Nigeria*** - legal aspects
- ***Poland*** - legal definition of 3D cadastral objects; pilot project; 3D cadastral surveys guidelines/directives
- ***Portugal*** - geometric description of properties (currently 2/3 text based); establishing a country-wide 2D cadastre
- ***Serbia*** - 3D cadastre data model (research phase); legal aspects; raising awareness for the need of 3D cadastre
- ***Singapore*** - legal aspects - legislations related to the vertical dimension; organizational aspect; 3D software
- ***South Korea*** - surveying methods; quality insurance
- ***Sweden*** - 3D property formation advance; 3D ownership apartment in existing tenancy apartments issue
- ***Switzerland*** - Adaptation of the legal basis and development of the data model of cadastral surveying (DCDB); legal definition of vertical limitation of a parcel; education and training of professionals
- ***Trinidad and Tobago*** - gaining governmental support; attaining financial support;

[6] Building Information Modelling

- ***Turkey*** **-** 3D data availability; cadastral data quality; legal issues; relevant professionals capacity building

In addition to underlining the top challenges, the participants were asked to indicate whether relatively to the 2014 prospects, any of the planned developments exceeded the expectations or on the contrary, unfolded slower than anticipated.

In China real 3D cadastre and information systems are built in Shenzhen to support urban planning and management. Switzerland reports an even faster development in techniques for data acquisition and contemplating ways of integrating 3D point clouds within the cadastral systems. New aerial photography and high resolution orthophoto in addition to LiDAR data were acquired earlier than predicted in Trinidad and Tobago. Even though no practical progress was made in Serbia, research has been conducted. In Singapore, a faster technological development was achieved in terms of 3D data collection, management and visualization.

Figure 5: 3D Cadastre Pilot Project - Turkey (*source – General Directorate of Land Registry and Cadastre* website)

On the down side, Argentina, Israel and South Korea indicate that overall expectations progresses slower than planned. In Nigeria, Switzerland, Singapore and Poland the legal aspects move forward rather in moderate pace. There are no regulations in Poland, despite the popularity of the subject. In Switzerland, the amendment of the legal framework in regard to 3D cadastre, is delayed. Furthermore, there are still important issues remaining with no answer, such as: topology and standardization of BIM. Croatia reports postponement in registration of public utility infrastructure. In Trinidad and Tobago the updating of the revised georeferenced cadastral index has not been completed just yet. Sweden mentions that object-oriented register is still an undergoing process and the formation of ownership apartments not proceeding as foreseen.

However, there are a few pilots undertaken on the way to 3D cadastre implementation: Turkey mentions a recently commenced project, initiated by the General Directorate of Land Registry

and Cadastre (GDLC), named '3D Cadastre'. The main goal of the project is creation of 3D building models for visualization purposes. Furthermore, as demonstrated in *Figure 5* above, legal information can also be viewed[7]; in the Netherlands, a pilot project involving the registration of Delft's railway station is completed (*Figure 6*). This is the first 3D registration of a multi-level ownership rights in the country (Stoter et al., 2016). The data can be viewed on a 3D pdf file; Switzerland has undertaken pilots for a digital documentation of condominiums; in Israel a prototype for 3D Cadastre registration is being developed in a joint project between academia representatives (*Israeli Institute of Technology*) and the *Survey of Israel*; and in Malaysia, the *Mass Rapid Transit* rail system, the first case of a 3D above ground infrastructure registration in an urban environment, is impending.

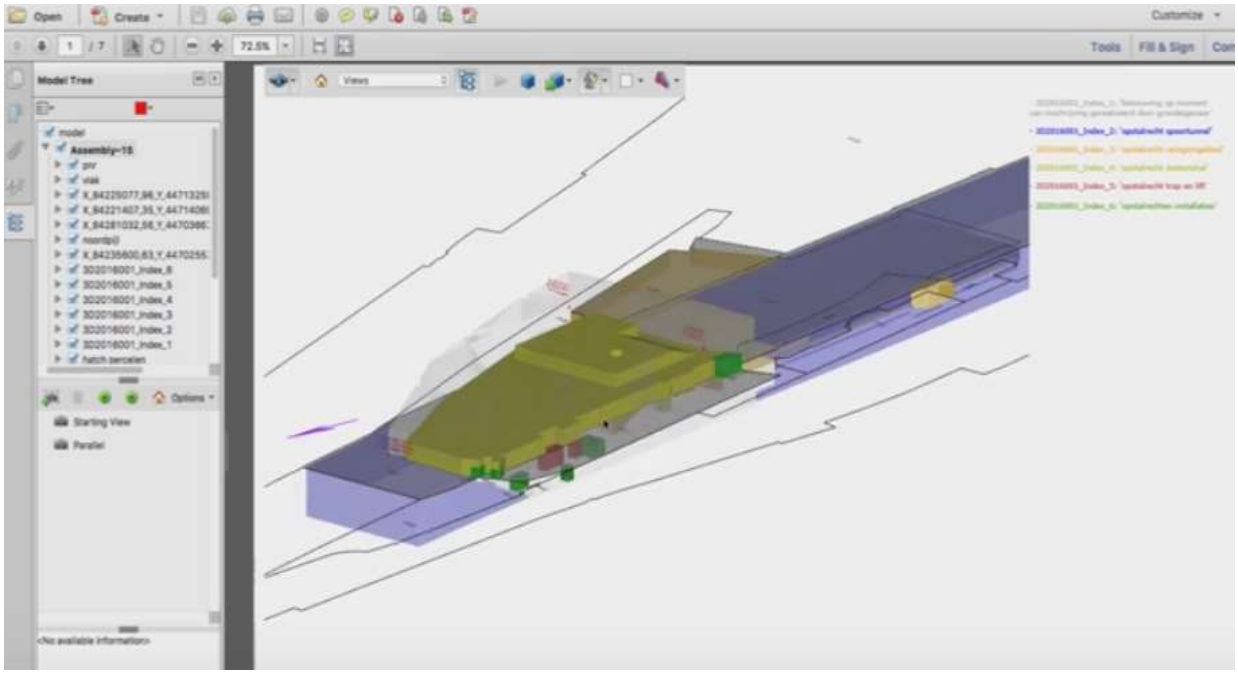

Figure 6: 3D Cadastre Pilot Project – Netherlands *(source – Netherlands Kadaster)*

Regarding adoption and/or establishment of new legislation which would facilitate the registration of 3D units, Malaysia reported that minimum depth for surface parcels has been redefined in order to allow stratum title registration. In Israel the 33rd amendment of the Land Law, which formally authorizes the registration of volumetric units, has been passed by the Knesset in December of 2018. In Singapore, the legislation is under revision to enable 3D support.

4.2 Expectations for 2022

Most of the countries haven't replied or only partly addressed this part of the questionnaire. In some case no expected changes were reported or the country stated that it is difficult to estimate what the future holds. Nevertheless, certain participants did share their views. Australia Queensland expects the underground network legal objects which contain above surface

[7] A short video describing the pilot project is available at the following link (in Turkish): https://www.tkgm.gov.tr/tr/icerik/3-boyutlu-kadastro-projesi

segment to be registered in the DCDB as 3D object rather than 2D footprints and automated examination to be performed. Furthermore, the DB is to be LADM based and the parcels represented as 3D objects. In Canada, different kinds of real rights objects are planned to be identified on the cadastral maps in the near future. China anticipates all networks to be fully digitized. The registration of title information and the cadastral transactions is expected to be under the responsibility of Cadastral and Land book agency in Croatia. Cyprus currently examines ways to upgrade their registration system and the D, as well the possibility of applying ArcGIS Pro 3D analysis Tools. Hellenic Cadastre is scheduled to be fully operational in 2022 which would serve as a solid basis for incorporating the 3D cadastre aspects into the system, both from legal and technical points of view. In Hungary a new 3D cadastral project is on the 2019 agenda. Various changes are expected in Malaysia, among them: volumetric units will be allowed for airspace parcels and enable overlapping constructions (e.g. bridges above roads), a LADM-based formal 3D model is planned to be operational, as well as 3D Marine boundaries. In Hungary networks are expected to be integrated into the land administration system and be registered as 3D parcels. Survey plans would provide 3D coordinates and 3D parcels would be represented in the DB. Singapore also plans on expending their technical capabilities which would include: 3D representation on cadastral maps, storing of 3D parcels geometry in database and to have tools for special validity checks. Switzerland underlines the necessity of legislation amendment and considers revision of the legal basis and technical regulations by 2022. In Trinidad and Tobago some changes in the legal frame and the registry might occur as well which would motivate an adoption of a formal model. A 3D Cadastral System based on the LADM and other ISO and OGC standards, which will have a substantial impact on legal, regulatory, organizational and technical aspects, is under discussion and design in the *Netherlands Cadastre, Land Registry and Mapping Agency.*

5. CONCLUSIONS

According to the initial analysis based on the information provided in the submitted surveys, a steady progress can be observed worldwide. Some effort is dedicated toward the technical aspect as 3D enabling technologies are becoming more and more available. Essentially all participating countries operate a digital cadastre, hence aiming at improving its capabilities in storing, visualization and dissemination of 3D related data. Some countries are dedicated to modernization of their legal system to allow registration in strata for all types of 3D units. Other countries are at the research state for developing a formal model, primarily LADM - based. Furthermore, ambulatory boundaries in general and marine cadastre in particular are receiving more attention, mainly in view of the increasing natural resources exploration activities, such as oil and gas as indicated by Nigeria and Trinidad and Tobago.

A few countries are standing out and leading the field. Malaysia (certified stratum plans) and China (3D models for 3D parcel representation) have made impressive advancement in the technical aspect, as well as Finland. Israel made a noticeable step forward with the passing of the 3D cadastre amendment to the Land Law.

However, in spite of the growing demand for 3D cadastre, only few countries can proudly declare operating a fully functional 3D system, with respect to individual requirements for a 3D cadastre in each jurisdiction. There are functionality limitations either in the legal,

organizational or the technical aspects as stated previously. The current focus is still on apartments' registration, nevertheless, the future goals are more overlapping rights registration and legal definition of 3D volumetric individual parcels oriented.

REFERENCES

Keat Lim C, Chee Hua T. and Kean Beng D.L., (2018). "Proposed Legislation For 3D Cadastre In Malaysia", FIG Congress 2018, Istanbul, Turkey

Kitsakis D., Paasch J. M., Paulsson J., Navratil G., Vučić N., Karabin M., El-Mekawy M., Koeva M., Janečka K., Erba D., Alberdi R., Kalantari , Z. Yang M., Pouliot J., Roy F., Montero M., Alvarado A. and Karki S., (2018), "3D Cadastres Best Practices, Chapter 1: Legal Foundations", FIG Congress, Istanbul

Lemmen C., van Oosterom P., (2003). 3D Cadastres (Editorial)", Computers, Environment and Urban Systems, 27(4), pp. 337-343

van Oosterom P., Dimopoulou E., (2018). "Introduction to the Special Issue: Research and Development Progress in 3D Cadastral Systems", ISPRS International Journal of Geo-Information, MDPI AG, 7(2), pp. 4

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

Rajabifard A., Agunbiade M., Kalantari M., Yip K.M., Atazadeh B., Badiee F., Bin Isa D. M. N., Bin Adimin M. K., Chan K. L., Aien A., Olfat H., Shojaei D. and Anaraki M. R., (2018). "An LADM-Based Approach For Developing and Implementing A National 3D Cadastre – A Case Study Of Malaysia", 7th International FIG Workshop on the LADM, Zagreb, Croatia

van Oosterom P., (2013). "Research and development in 3D Cadastres", Computers, Environment and Urban Systems, 40, pp. 1-6

Stoter J., Ploeger H., Roes R., van der Riet E., Filip Biljecki and Hugo Ledoux, (2016). "First 3D Cadastral Registration of Multi-level Ownerships Rights in the Netherlands", 5th International FIG Workshop on 3D Cadastres, Athens, Greece

van Oosterom P., Stoter J., Ploeger H., Lemmen C., Thompson R. and Karki S., (2014). "Initial Analysis of the Second FIG 3D Cadastres Questionnaire: Status in 2014 and Expectations for 2018", 4th International Workshop on 3D Cadastres, Dubai, United Arab Emirates

van Oosterom P., Stoter S., 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, Morocco

BIOGRAPHICAL NOTES

Anna Shnaidman is a former Geophysical Surveys and Research Administrator in the Research Division at the Survey of Israel and a Part-time Lecturer in the Department of Civil Engineering at the Technion - Israeli Institute of Technology. She received her BSc (2008, Cum Laude) and

MSc (2010) and PhD (2016) degrees in Mapping and Geo-Information engineering from Israeli Institute of Technology. Dr. Shnaidman is a Licensed Surveyor as well. Since September 2018 she is a postdoctoral researcher at the 'GIS Technology' Section, OTB Department, Faculty of Architecture and the Built Environment, Delft University of Technology, the Netherlands.
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'.

Alias Abdul Rahman is a Professor at 3D GIS Research Lab, Department of Geoinformation, Universiti Teknologi Malaysia (UTM). He received his PhD from the University of Glasgow, United Kingdom and MSc from ITC, the Netherlands, and BSc in Surveying and Mapping Sciences from North East London Polytechnic, U.K. Actively involves in several international conference series such as 3D Geoinfo conference, GGT conference series. He is co-chair of the FIG Working Group on '3D Cadastres'.

Christiaan Lemmen is full Professor Land Information Modeling at the Faculty of GeoInformation Science and Earth Observation of the University of Twente in the Netherlands. His other main job is as Senior Geodetic Advisor at Kadaster International, the international branch of the Netherlands Cadastre, Land Registry and Mapping Agency. He is director of the OICRF, the International Office of Cadastre and Land Records, one of the permanent institutions of the International Federation of Surveyors (FIG). He is co-editor of the International Standard for the Land Administration Domain, ISO 19152 and the designer of the Social Tenure Domain Model (in co-operation with UN HABITAT and FIG). He holds a PhD from Delft University of Technology, The Netherlands.

Sudarshan Karki is a Senior Spatial Information Officer in the Department of Natural Resource, Mines and Energy, Queensland Government, Australia. He is a surveyor and has completed a Master of Spatial Science by Research at the University of Southern Queensland (USQ) in 2013 and a professional Master's Degree in Geo-informatics from ITC, The Netherlands in 2003. He has continued his research interest in 3D cadastre and is currently undertaking his PhD research at UNSW.

Hendrik Ploeger obtained master degrees in law from Leiden University and VU University Amsterdam. In 1997 he received a PhD from Leiden University. He is currently associate professor at Delft University of Technology, Faculty of Architecture and the Built Environment, Delft University of Technology, the Netherlands, He also holds the endowed chair in land law and land registration at VU University, Amsterdam (2009-2019). He was chair of the FIG Working Group on '3D Cadastres' from 2002 to 2006.

CONTACTS

Anna Shnaidman
Delft University of Technology
OTB, Section GIS-technology
P.O. Box 5030
2600 GA Delft, the Netherlands
Tel. +31 15 2786950
E-mail: A.Shnaidman@tudelft.nl
Website: http://www.gdmc.nl

Peter van Oosterom
Delft University of Technology
OTB, Section GIS-technology
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

Alias Abdul Rahman
Department of Geoinformation,
Faculty of Built Environment and Surveying,
Universiti Teknologi Malaysia
81310 Johor Bahru, Johor, Malaysia
Tel.: +6013-7490452
E-mail: alias@utm.my
Website: http://builtsurvey.utm.my

Christiaan Lemmen
University of Twente
Faculty of Geo-Information Science and Earth Observation/ITC
P.O. Box 217
7500 AE Enschede
THE NETHERLANDS
Phone: + 31 6 52481717
E-mail: c.h.j.lemmen@utwente.nl
Website: www.itc.nl
and
Cadastre, Land Registry and Mapping Agency
Kadaster International
P.O. Box 9046
7300 GH Apeldoorn
THE NETHERLANDS
Phone: +31 88 183 4417

E-mail: Chrit.Lemmen@kadaster.nl
Website: www.kadaster.nl

Sudarshan Karki
Queensland Government, Department of Natural Resources, Mines and Energy
Lvl 17, 275 George Street, Brisbane, Queensland 4001, Australia
Tel. +61 7 3330 4720
E-mail: Sudarshan.Karki@dnrme.qld.gov.au
Website: https://www.dnrme.qld.gov.au/

Hendrik Ploeger
Delft University of Technology
OTB, Knowledge Centre Open Data
P.O. Box 5030
2600 GA Delft, the Netherlands
Tel.: + 31 15 2782557
E-mail: h.d.ploeger@tudelft.nl
Website: www.juritecture.net