Steps towards 3D Cadastre and ISO 19152 (LADM) in Israel

Yaron FELUS, Shimon BARZANI, Alisa CAINE, Nimrod BLUMKINE, Israel and Peter VAN OOSTEROM, the Netherlands

Key words: Israel, 3D Cadastre, LADM, SDI, Data Transfer

SUMMARY

This paper contains the results of the 3D Cadastre and LADM (Land Administration Domain Model) investigations in context of possible future renewal of the Cadastral database at the Survey of Israel. The two topics of 3D Cadastres and LADM are highly related and therefore this paper covers both aspects. After recapturing the past 3D cadastre investigations in Israel and analyzing the current Israeli cadastral procedures, an initial step towards a 3D LADM country profile and recommendations to realize the inclusion of 3D in the future workflow of the registrations are given.

Steps towards 3D Cadastre and ISO 19152 (LADM) in Israel

Yaron FELUS, Shimon BARZANI, Alisa CAINE, Nimrod BLUMKINE, Israel and Peter VAN OOSTEROM, the Netherlands

1. INTRODUCTION

Israel is a relatively small country, with a rapidly growing population, the pressure on the available land/space is increasing, and today's technology is enabling 3D functionality as proven is some other countries; e.g. China (or other application areas).

Israel was among the first countries in the world to address the topic of 3D representations in the cadastral registration (Benhamu and Doytsher 2001, Forrai and Kirschner 2001, Grinstein 2001, Sandberg 2001, Benhamu and Doytsher 2003, and Sandberg 2003). This was reinforced by a two year 3D Cadastre R&D project during the years 2002-2004 (Shoshani, Benhamu, Goshen, Denekamp and Bar 2004, Shoshani, Benhamu, Goshen, Denekamp and Bar 2005, Benhamu 2006). This was not by coincidence, as Israel is a relatively small country, with a rapidly growing population, the pressure on the available land/space is increasing. A decade ago there was no country in the world having an operational Cadastre including the legislation, 3D survey plans/ mutation plans, 3D Cadastral database, and 3D dissemination. Technology was still limited (e.g. the spatial DBMS did not yet support 3D volumetric primitives), and legislation needed adoptions. Therefore, the early R&D in Israel was not directly transformed in an operational system, most likely due to a mixed set of factors: legal (introducing new law or changing existing regulations takes time), organizational (financial/ cost aspects and cooperation with partners such as licensed surveyors and the land registry office, Ministry of Justice), and technical (no operational 3D Cadastral system implementations available).

Despite the fact that the 3D representation was not yet included in the Israeli registration, the 3D interest always remained and further studies where conducted, covering both the legal (Caine 2009, Sandberg 2014) and technical (Peres and Benhamu 2009) aspects. This puts Israel in a position of a high knowledge level. The starting position is healthy and based on well-investigated recommendations from the mentioned activities. Further, the pressure on land/ space has only increased over the last decade, which further emphasizes the importance of 3D Cadastral registration in the future of Israel. Now, after a decade of more experience with real-world (3D) developments in Israel, other countries also progressing, and an accepted international ISO 19152 standard for Land Administration supporting 3D representations, it is time to realize the 3D Cadastre in Israel.

The development of this LADM country profile is a joint activity involving the Israeli key players: That is, besides the Survey of Israel, also the Land Registry (especially when also considering to register apartments, condominiums in 3D), Israel Land Authority (93% of the land in Israel is in the public domain, and ILA is responsible for managing this land), and the licensed surveyors (creating the new 2D and 3D parcel representations). Different organizations are involved and cooperation is needed, not only for creating the new Israeli LADM country profile, but also to agree on new functionality (such as 3D Cadastre) and most important for data exchange, data synchronization and joint data delivery supporting the daily activities. This setting asks for an information infrastructure approach, which is also assumed in ISO 19152. Various organizations are, or will be in the near future, involved in maintaining and disseminating the land administration information. In addition with emphasis on the 3D component, there may be even more need for an information infrastructure approach (or spatial data infrastructure, when the spatial aspect is emphasized). For example the underground and above ground legal spaces in a 3D cadastre are often related to real world (physical) objects, such as tunnels, underground parking or shops, above road constructions (buildings), etc.

The remainder of the paper is organized as follows. Section 2 describes the background and history of the 3D Cadastre (research) activities in Israel, while Section 3 gives an overview of the current cadastral procedures and land model in Israel. The scoping of the Israeli 3D LADM country profile, the SDI context, and initial conceptual model will be described in Section 4 of this paper. The complete 3D Cadastre workflow and options for its implementation are discussed in Section 5. The main conclusions and indication for next steps and future work are finally given in Section 6.

2. BACKGROUND

As indicated in the introduction, Israel has already quite a long track record in exploring 3D Cadastre solutions. It is therefore wise to remember the earlier recommendations of which the main two aspects are (Shoshani, Benhamu, Goshen, Denekamp and Bar 2005): 1. prepare appropriate legislation and regulation, 2. foundation of 3D Cadastre solution is the 3D sub-parcel principle; see Figure 1. The 3D sub-parcel concept is based on subdivision of the unlimited column of space implied by the 2D surface parcel into at least one completely bounded 3D volume and a remaining (unlimited) space. The bounded 3D volume is within the column of the 2D surface parcel. This approach fits relatively well in the current approach with some extensions. In addition, the recommendation also included more detailed suggestions how to represent the third dimension (analytical x,y,h coordinates with h absolute, that is in orthometric heights above or below sea level) and 3D sub-parcel numbering (extension of current block and parcel number with additional sub-parcel sequence number).

The logic behind the sub-parcel is clear: the owner of the surface parcel (3D column of space) splits the owned space and sells one part to another party. For long infrastructure type of objects the result is that one object, such as a tunnel, is to be represented with many 3D sub-parcels. To each of the 3D sub-parcels the same right and party should be attached, both initially, but also in future transactions (e.g. tunnel is sold to a company). This is redundant information and error prone. It is better to allow 3D parcels crossing many surface parcels. They could be created in one transaction involving all surface parcels, each selling a part of their property, to create a single 3D subsurface parcel to which the right and party can be attached (for the tunnel). So far, the historic reflections on the sub-parcel concept. In Section 4 (question 3), the sub-parcel issue is addressed again. As explained in that section, it has recently been decided that whilst being a necessary stage in the process of creating a new 3D parcel, it will not be the final stage. Within a cadastral block (‘gush’) the virtual/ temporal sub-parcels are merged into a single larger and connected 3D parcel with same right and party information attached.

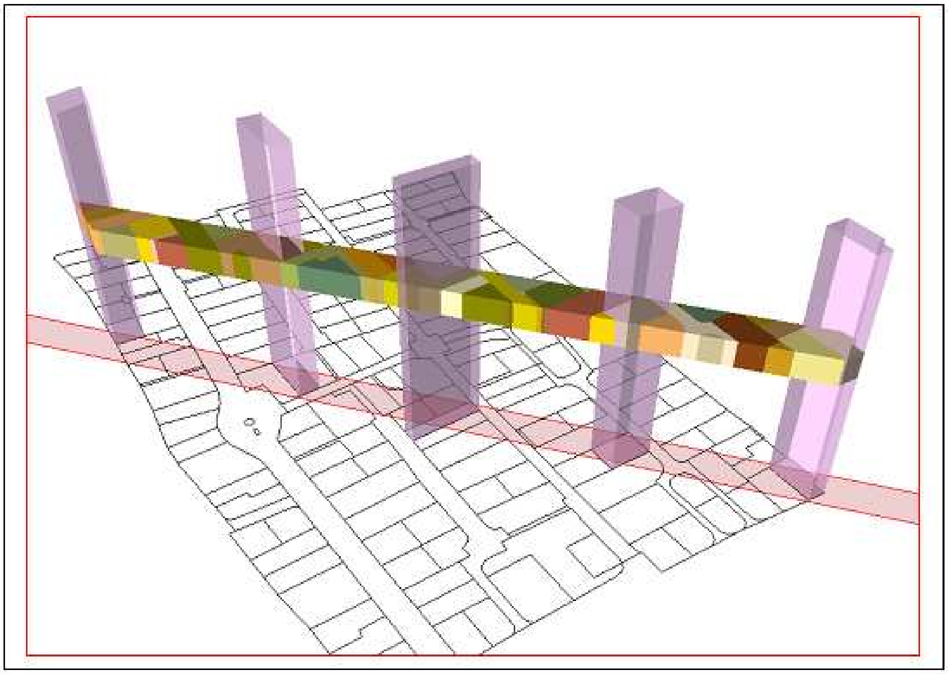

Figure 1. 3D Presentation of the spatial sub-parcels on the background of the existing land parcels. Source: (Shoshani, Benhamu, Goshen, Denekamp and Bar 2005)

A more in-depth legal analysis concluded in 2009 (Caine 2009): 'Using existing legal tools (notably leases, easements and condominiums laws) without changing their essence and features would create a huge gap between factual and legal reality,… To date, there seem to be consensus among all those versed in the subject that a legislative amendment is necessary in order to make special rights possible and viable in Israel.' Next the above cited paper describes four main legal paths which can be taken in order to reach that aim:

1. use of the existing legal tools and stretch them to support 3D spatial parcels;
2. adopt a "non invasive" legal technique (as there is no direct legal obstacle to the creation of 3D spatial parcels under Israeli legislation);
3. establish an 3D "object registry", external to the Land Registry, in which rights to subterranean and aerial objects could be registered and managed; or
4. establish specific legislation for the creating spatial parcels.

After discussing the benefits and drawback of the various options in the Israeli setting, it was stated that the preferred position of the Ministry of Justice was the fourth option. This was among others based on statements by Justice Barak (and supported by Justice Rivlin) in the context of the Supreme Court case Akonas vs. State of Israel (Civil Appeal 119/01 2003) who urged 'the legislature to consider the topics of subsoil ownership…' (Caine 2009). It must be noted that there are always multiple legal option/routes that could work and therefore this is not a black/white decision. If something is not explicitly included in a law, it can often be included in practical procedures, directions, guidelines or regulations of the relevant authorities (e.g. Survey of Israel and Land Registry). Also, the legal aspects are connected to practical organizational aspects: who registers 3D spatial parcels and how is this related to

other registrations (also see option 3 above). Most important aspect is that all stakeholders agree and are able to design a practical approach for 3D cadastre.
Another aspect to consider in Israel and related to 3D Cadastre concept is spatial planning (and related law and regulations) as raised by Sandberg (2014), which is also moving towards multi-layered and sub-surface planning. The National Master Plan 40 is being prepared and the 2011 policy paper describes two main goals, which have both a 3D aspect: the improvement of protection against attacks and better utilization of sub-surface. When this Master Plan is to be realized, it will generate more cases for 3D cadastral parcels in the future.
Legal inspiration, according to the option 4 thinking, can be found is some other countries; for example in Queensland, Australia (Karki, Thompson and McDougall 2013). The Queensland Land Title Act (Queensland Government, 1994) specifies two methods for defining 3D cadastral objects: Building Format Plans (BFPs with '2D' floor plans for the different levels) and Volumetric Format Plans (VFPs with true 3D geometric description). In addition to the Land Title Act there are directions specifying details for the submission of survey plans (or mutation plans according to Israeli terminology): Registrar of Titles Directions for Preparation of Plans, Section 10 for VFPs (DNRM 2013).
Similar to the scoping questions raised by the FIG Working group 3D Cadastres (van Oosterom, Stoter, Ploeger, Thompson and Karki 2011) Israel, as any other country, has to consider where, when, and how to apply 3D Cadastre. It may be wise to design a more generic solution, from legal, organizational and technical points of view, of which initially only the most urgent cases will be represented in 3D. However, it is to be expected that in less urgent cases the needs or expectations of society in the future may also change and it is wise to anticipate or even stimulate these future uses of 3D registration (e.g. registration of air-space or the registration of apartments in 3D). Apartments or condominiums are the most frequent type of 3D objects to which RRRs are attached, and it could be argued that these are managed quite well even without a 3D Cadastre. However, a 3D Cadastre would provide easier to use representations. In addition, there are occurring more and more complicated cases where the condominium needs to be connected to a 3D volume (above or below the surface) from an adjoining parcel. This is nowadays often solved in a suboptimal way (e.g. a lease, but unaptly describing the proprietary relationships and rights), and a 3D Cadastre solution would clearly bring benefits. It is therefore now the right time to reconsider earlier proposals made during the past decade in Israel.
Other relevant issues to consider are of practical nature: how well will a future 3D Cadastre extension fit within the current systems, which are using an Oracle database and Esri ArcGIS. Since a number of years Oracle spatial supports a 3D volumetric geometric primitive (Kazar, Kothuri, van Oosterom and Ravada 2008). Note that Oracle's solid type does not allow inner ring in faces (must be split in multiple faces, which is always feasible). Esri's Geodatabase does not yet have a 3D geometric primitive. However, a multipatch can be used, and there is a function to check is a volume is enclosed (IsClosed3D_3d), but validation rules are not explicitly described. For example, it is unclear if dangling faces (patches) or self-intersection is allowed. So, most likely the validation should be done elsewhere (e.g. in Oracle spatial or own code). Currently both Oracle and Esri do not yet support 3D topology structure.

3. CURRENT CADASTRAL PROCEDURES AND LAND MODEL

The current cadastral procedures and practice at the Survey of Israel are based on approval of block maps and mutation plans (Forrai, Murkes, Voznesensky and Klebanov, 2004). The Israeli setting is further characterized by the national policy of having a small government and significant role for industry. This results among others in the role of licensed surveyors (commercial sector) preparing the mutation plans according the prescribed rules and also in the IT industry, having an important role in system development.

The Israeli national cadastral database, the BNKL, is stored in an Oracle database and managed using an Esri's ArcGIS. The parcels are the smallest area unit in the cadastral database and currently limited to 2D representations. A number of parcels is grouped in a block ('Gush'), traditionally a map sheet and used in the parcel numbering hierarchy. The parcels consist of arcs and nodes in topological relationships, so the parcels do not overlap. As there are no left and right references in the parcel_arc table, the topological structure is not explicitly stored. This results in each parcel having a convenient complete polygonal description, but also some redundancy as normally every boundary is stored twice. Figure 2 illustrate these key classes, tables in the database. The changes (new, deleted, updated parcels) are originating from a mutation plan ('Talar'), which are created and submitted to the Survey of Israel by external, licensed surveyors. The mutation plans are submitted as AutoCAD files (DWG format). In a mutation plan, the parcels can be split, merged or a combination hereof. After a quality control procedure of the Survey of Israel and approval of Land Registry (including assignment of new parcel numbers), the changes are included in the BNKL and also registered of the Land Registry (Ministry of Justice). The parcel and gush tables in the BNKL database contain the current representations, while history is maintained via the archive of mutation plans ('Talar') and historic parcels and blocks ('Gush') are moved to different tables.

An, exceptional, alternative to create (3D) parcels with rights attached is according to the Israeli 'Settlement of Right' process. Settlement of Rights is a public proceeding by which plots which were previously non registered or registered without proper mapping or without mapping at all, an approximate size and verbally described boundaries (in LADM terms: textual description of the boundary of a LA_SpatialUnit) become settled plots, in which the parcels have verified owners. The Israeli legislative states that title registered in settled parcels is conclusive proof. Under the Law, there is no limitation to the creation of a 3D parcel by Settlement of Right, once the Law will make the existence of such a parcel possible.

The Land Administration Domain Model (ISO-TC211 2012, van Oosterom, Lemmen and Uitermark 2013) provides an international standardization of the key concepts of land administration. LADM covers both the survey, cadastral map and land registry (legal) information; see Figure 3. There are several good reasons to consider adopting LADM when (re)developing a cadastral database, and to name a few: collective experience of experts from many countries, meaningful data exchange (within country/SDI-setting or between countries/states), integrated 2D and 3D representation of spatial units, supports both formal and informal rights (RRRs), and explicitly models the links between the essential land information data (as in cadastral map or land registry) to source documents, both spatial (survey) and legal (title, deed). More motivation to consider LADM implementations was discussed at 5th LADM workshop (Kalantari, Rajabifard, Urban-Karr and Dinsmore 2013, and Thompson 2013).

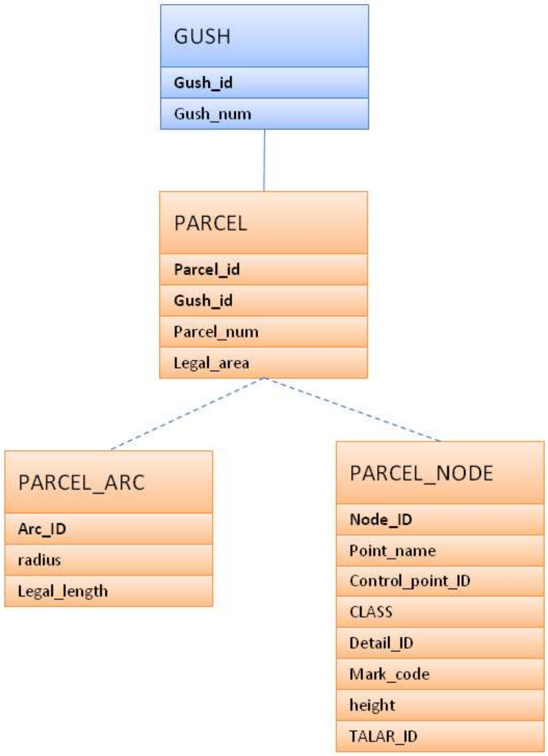

Figure 2. The key classes, tables in the database (Source: slides from Moshe Yaniv, 26 January 2014)

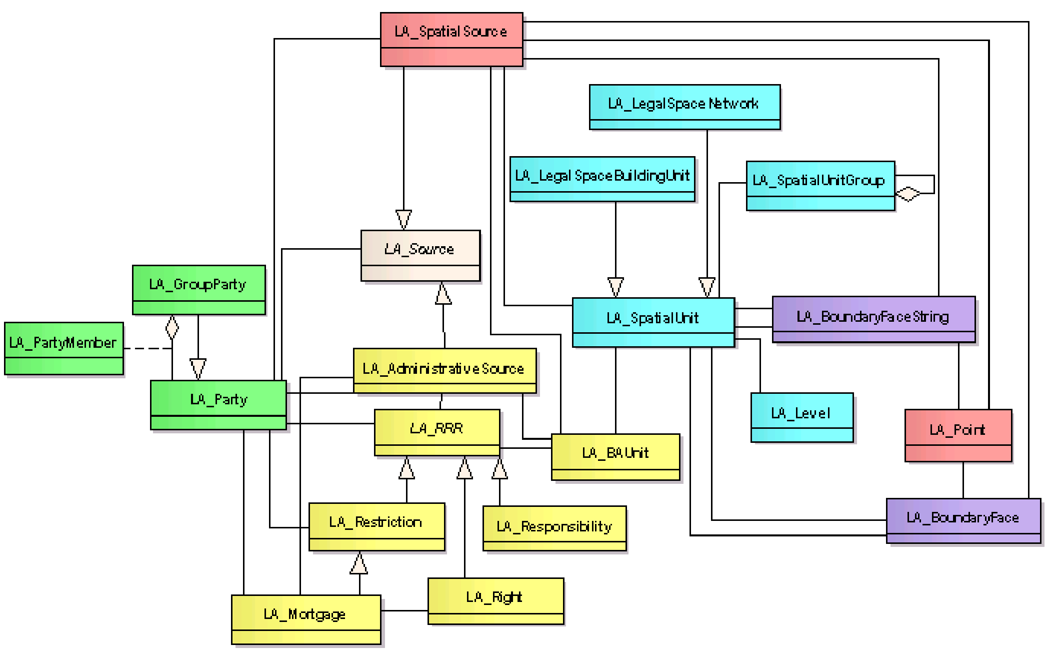

Figure 3. The classes of the LADM (ISO-TC211 2012)

4. DEVELOPING A 3D LADM COUNTRY PROFILE FOR ISRAEL

During the various meetings and other communication means (mainly emails) the main scoping questions were addressed, giving clear indications for further developing the Israeli 3D LADM country profile. The four scoping questions raised by the FIG Working group 3D Cadastres (van Oosterom, Stoter, Ploeger, Thompson and Karki 2011) have now been answered and indicate where, when, and how to apply 3D Cadastre in Isreal:

1. What are the types of 3D cadastral objects? Are these related to (future) constructions (buildings, pipelines, tunnels, etc.) or can these be any part of the 3D space, both airspace or subsurface?
   Answer: Both a. related to (future) constructions (buildings, pipelines, tunnels, etc.), and b. any part of 3D space (airspace, subsurface). This in order to make the registration system future proof. Initially not all options may be used and supported in the system, but the model should enable representing all these situations.
2. Use 3D Parcels also for simple apartments/ condominium buildings with possible related (subsurface) facilities such as storage or parking or use more traditional 2D floor plans for the different levels?
   Answer: Not in short term (use 2D floor plans), but may be in longer term. As this is a very common case, happening very often this is also an important aspect. Instead of using exact height information, also estimated heights can be used as for example in Spain's 3D Cadastre solution (Olivares García et al, 2011).
3. Are 3D Parcels for infrastructure objects, such as long tunnels, pipelines, and cables, divided by surface parcels or are these represented by one object?
   Answer: Only divided by blocks ('Gush'). So, join sub-parcels within block, which is a slight modification to the original Israeli 3D sub-parcel approach (see Section 2), but joining sub-parcels immediately after creation into a larger 3D parcel with its own unique number, will result in a more manageable registration. In order to overcome the last drawback of splitting at block boundaries, especially with infrastructures such as roads or railways, a grouping of these 3D parts is proposed in a kind of "uber parcel". In LADM terms this could be a LA_SpatialUnitGroup with no direct rights attached (in contrast to grouping in LA_BAUnit, which would also have direct rights attached).
4. For representation of 3D parcel: does a legal space have its own geometry or is it specified by referencing to existing topographic objects?
   Answer: Own geometry. This similar with today's practise to 2D parcels, also having their own geometry and makes the solution more robust and not depending on changes in the real world.

It may be wise to design a more generic solution, from legal, organizational and technical points of view, of which initially only the most urgent cases will be represented in 3D. However, it is to be expected that in less urgent cases the needs or expectations of society in the future may also change and it is good to anticipate or even stimulate these future uses of 3D registration (e.g. registration of air-space or the registration of apartments in 3D). Another scope/ modelling question is related to the Earth surface (terrain elevation).

5. Should we define a surface that specifies whether a parcel is above or under ground level (see Figure 4)? How should ground level be defined?

Answer: It is often very relevant to know whether a parcel above, below or in mixed position w.r.t. Earth surface. So, for 3D parcels it may be tempting to use relative height w.r.t. Earth surface. However, as the Earth surface may change over time (due to natural or man-related causes) this is not a stable reference, and it is therefore advised to have at least absolute height in coordinates of 3D parcels and maintain and use Earth surface (height) description as separate registration. During data dissemination and visualization 2D parcels can then be projected on Earth surface and combined with 3D parcels (via SDI approach).

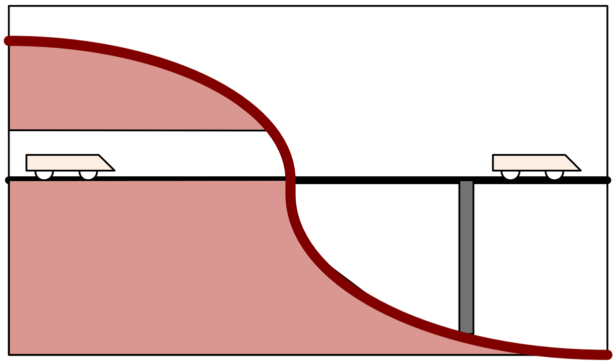

Figure 4. The railway parcel is above and under the ground.

Investigating exemplary cases, such as the apartments/ condominium buildings case in question 2, and the tunnel/pipeline discussion in question 3, is important. Analysing these cases then better support scoping and taking future proof design decisions. Another exemplary case is the use of 3D space below the surface/ property of another parry. The Israeli cadastral database nowadays is still two-dimensional. It was discussed that in the 3D Cadastre, the 2D parcels should be interpreted as 3D parcels as vertical columns based on the 2D geometry. These 3D parcels can then have 3D exclusions or 3D additions to represent using the space below someone elses property (beneficiary party gets the additional 3D space, the other party get exclusion of this space form his property). This raises the following LADM modelling question:

6. The parcel 2D records (base properties) will be linked with these exclusions/ additions (see Figure 5). The question is how to define a parcel which is open on the side of top and/or bottom and bounded on the other sides?

   Answer: In LADM an elegant way to model the cases such as example in Figure 5 is as follows: use the LA_Level approach with a 2D parcel level and a 3D parcel level:
   - have 3 parcels (A, B, C) in 2D parcel level, implying 3D columns;
   - have 1 parcel (A-1+B-1) in 3D parcel level; and
   - use LA_BAUnit to combine C with A-1+B-1.

   Then the parcels A and B, both 3D columns, have exclusion (A-1+B-1) via the LA_Level approach. Parcel C has documented extension via LA_BAUnit grouping.

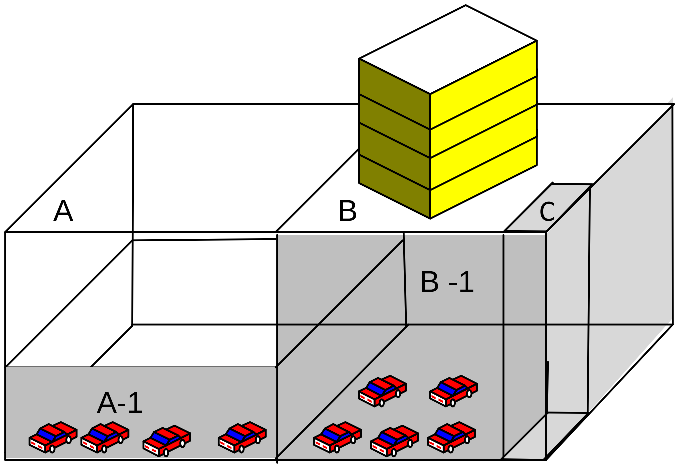

Figure 5. The parking lot parcel is composed out of the shaft parcel (C) which is infinite parcel A-1 which is the exclusion from parcel A and B-1 which is the exclusion from B

After the discussed scope and various design considerations (based on analysing the cases), the conceptual model for the Israeli 3D LADM country profile can be made. This country profile should both consider the current registration (in 2D) and the wishes for the future registration. Therefore the first step is analysing the key concepts in LADM and their counterparts in the actual registrations and link related concepts. In Table 1 the mapping of LADM and BNKL key concepts is given. It should be noted that for a nationwide 3D country profile this mapping should also include the mappings to the key concepts of other relevant registrations; that is, the registrations of Land Registry, Israel Land Authority, and perhaps even more organizations (e.g. geometries with legal implications resulting from spatial planning).

Table 1. An initial mapping between the key concepts of BNKL and LADM

BNKL	LADM	remark
Gush	LA_SpatialUnitGroup	
Parcel	LA_SpatialUnit	
Parcel_arc	LA_BoundaryFaceString	
	LA_BoundaryFace	No 3D currently in BNKL
Parcel_node	LA_Point	
Talar	LA_SpatialSource	
	LA_BAUnit	Not explicit in BNKL
	LA_RRR	In scope of Land Registry
	LA_AdministrativeSource	In scope of Land Registry
	LA_Party	In scope of Land Registry

It is required to make the relationships explicit (linking to concepts in the shared language of LADM) as these are crucial in the Information Infrastructure in a country, in which multiple organizations maintain and provide related (source) information. Figure 6 shows a UML diagram of the current registration in the initial Israeli country profile as specialization of LADM. The prefix 'IL_' is used to indicate the fact that this is the Israel country profile. The following inheritance relationships are shown IL_Parcel (from LA_SpatialUnit), IL_ParcelArc (from LA_BoundaryFaceString), IL_ParcelNode (from LA_Point), IL_Gush (from LA_SpatialUnitGroup), and IL_Talar (from LA_SpatialSource). The first step towards 3D parcels is the introduction of the 3D IL_BoundaryFace (from LA_BoundaryFace), but this needs to be further developed. The same is true for the administrative side of the Israeli LADM country profile.

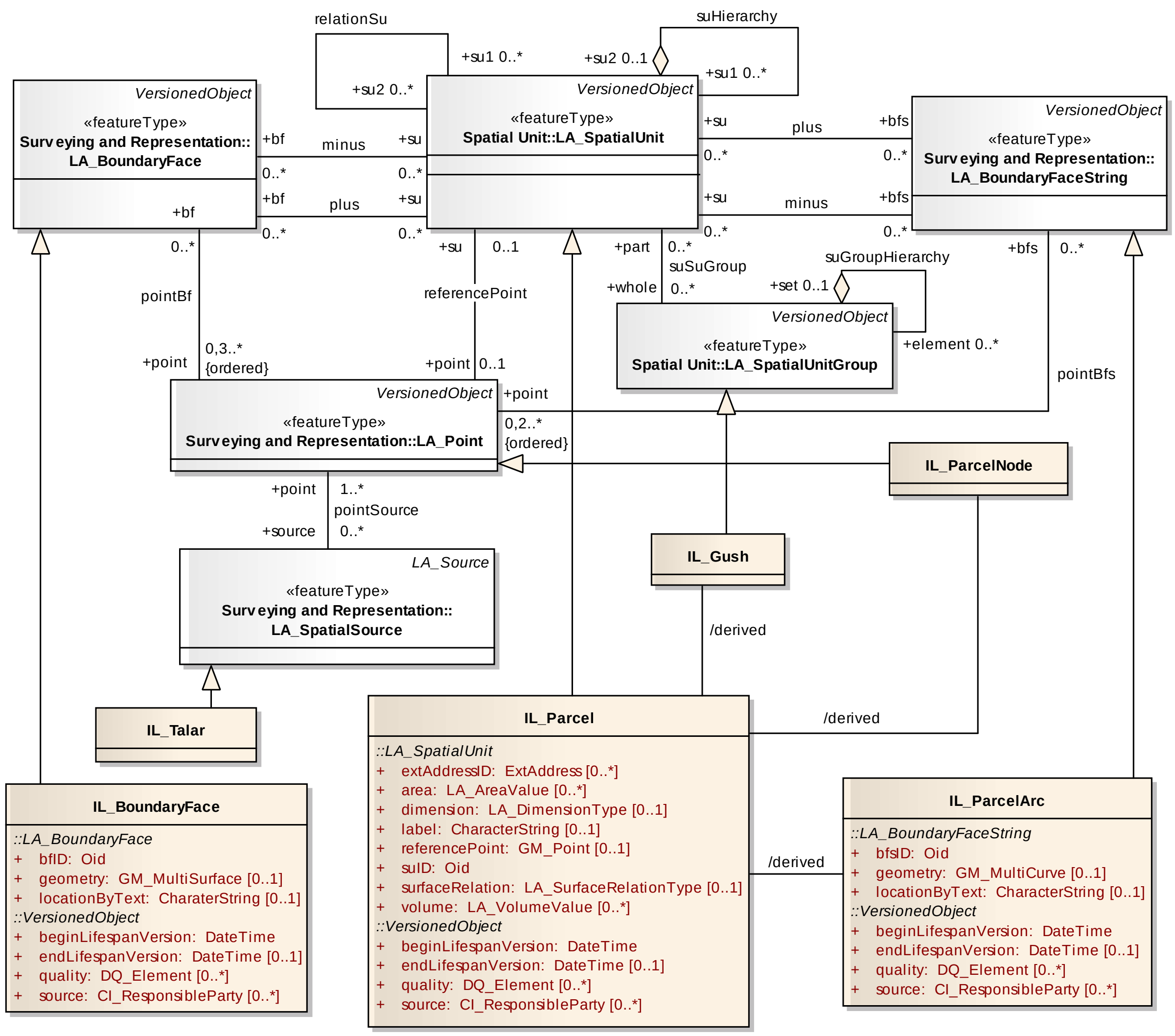

Figure 6. Current situation of spatial side of land administration in Israel, UML model of the initial Israeli country profile as specialization of LADM

5. 3D CADASTRE WORKFLOW

Realizing a cadastral registration with 3D support has impact on the complete workflow: from data acquisition until data dissemination in 3D and all steps in between. Figure 7 shows the seven steps of this workflow, which are identified and will be discussed in more detail below.

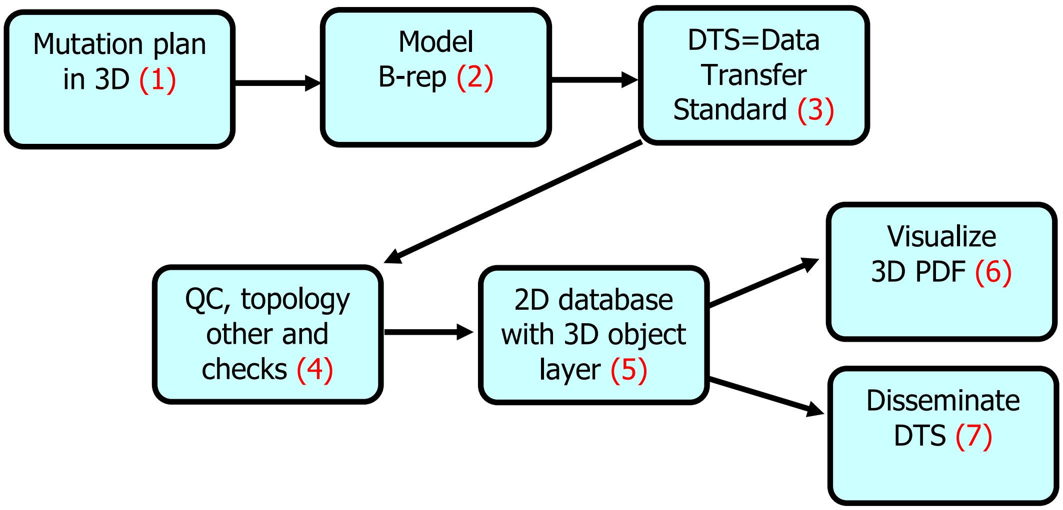

Figure 7. The 3D cadastre workflow

Steps 1 (survey or mutation plan in 3D) and 2 (B-rep of model) take care of providing the spatial data sources of the new 3D parcels. In cadastral context we are used to survey as basis to create the 3D geometries of parcels. However, direct survey in 3D, might be challenging, e.g. how to survey a subsurface object or an airspace object? Experience from Queensland, Australia shows that a lot of the submitted 'survey plans' (mutation plans) do seam to have a CAD origin. For existing physical objects with legal spaces attached, there are some methods to obtain the 3D geometries:

- Upgrade existing 2D floor plans to 3D volumes: manual initially, in the future more automation
- If no plans available, then do a survey. Laser scan based measurement may be more effective than Tachymeter

Today, new buildings are often directly designed in 3D. With some limited additional effort (and clear guidelines) it should be possible to create the relevant 3D cadastral objects. This illustrates that 3D Cadastral registration is not an isolated activity, but actually part of a complete spatial development workflow chain. For 3D models there are different options available than the obvious B-rep approach. For example: CSG (constructive solid geometry) or voxel representations. However, the B-rep approach is preferred, because this is also the approach used in the 2D cadastral modelling, but more importantly the B-rep models support well both survey and design originated 3D data.
With respect to step 3, the data transfer standard (DTS), there are again a range of options. One option is the encoding of a 3D parcel as a Solid in CityGML with LADM extension: DTS from Russian prototype (Vandysheva et al 2012). However, some other options for data transfer standard are available: LandXML (for which within OGC now the initiative has

started to develop a more modern variant, called InfraGML) or more building oriented standards such as BIM/ IFC. The next step (4) covers the automated quality check in 3D in order to assess if the data is complete, and if there are no geometry and topology errors. Queensland, Australia has implemented and highly automated the checking of the survey plans, which are submitted via ePlan, and with data encoded in LandXML. Based on over 20 years of experience, they developed formal validation rules to support digital lodgement of 3D cadastral plans (Karki, Thompson and McDougall, 2013). This was possible because of the solid legal basis of the Queensland Land Title Act (Queensland Government, 1994) with specification of various methods for defining 3D cadastral objects (Building Format Plans and Volumetric Format Plans) and additional directions specifying details for the submission of survey/mutation plans: Registrar of Titles Directions for Preparation of Plans, Section 10 (DNRM, 2013). Note that the 3D geometry aspect of the quality check if not trivial as there are various types of valid, but non 2-manifold 3D Parcels (Ying et al 2011, Thompson and van Oosterom 2012).
After checking and accepting the newly submitted 3D Parcels they have to be stored in the database (Step 5). For this the conceptual model (Israeli 3D LADM country profile, see Section 4) and transformation of this model into a technical database model (SQL DDL) are the foundation. This technical model in SOI context is realized using an Oracle database and Esri ArcGIS. Currently both Oracle and Esri do not yet support 3D topology structure. For data visualization (step 6) and data dissemination (step 7) it is again important to use well accepted standards and products. In the Netherlands experiments have been conducted based on 3D pdf (Stoter, Ploeger and van Oosterom 2013). For web based dissemination X3D (ISO/IEC 2007, ISO/IEC 2008) is a good option as illustrated in the 3D Cadastre prototype in Russia (Vandysheva et al 2012). The first time that the 3D web browser is used, the installation of an X3D-plugin (BS Contact from Bitmanagement) in the web browser is needed. An alternative which is supported natively in various browsers today is WebGL (Web Graphics Library). WebGL is a JavaScript API for rendering interactive 3D graphics within any compatible web browser without the use of plug-ins (as supported in Chrome, Firefox, Safari, Opera, Internet Explorer and many mobile browsers). WebGL is integrated completely into all the web standards of the browser allowing GPU accelerated usage of physics and image processing and effects as part of the web page canvas; source: http://en.wikipedia.org/wiki/WebGL.

6. CONCLUSION

The development of the Israel 3D LADM country profile, the conceptual model, needs to be a national activity (with initiating organization: SOI). The LADM provides standardized class names for spatial and non-spatial data and is therefore a good basis for national harmonization of land administration related information, maintained by various organizations. The unique identifiers form the important links between spatial and non-spatial data. The identifiers should not only be unique within a single organization, but should be globally unique and can be used in the context of the national SDI to realize references to objects in each others registrations. Besides specifying the classes, their attributes and relationships in the Israeli 3D country profile, also attention has to be paid to agreeing on the new code lists (including code list values) for spatial and non-spatial data, based as much as possible on accepted practices.

The LA_SpatialUnits are the "glue" joining the spatial description of land to the RRR aspects. LA_SpatialUnits are universal in their land administration application (ownership, easement, utilities, building,..). The LA_SpatialUnits can be documented according to a range of representations: from textual description to 3D topology structure (and the country profile needs to specify which exact representations are to be used). In any case, LA_SpatialUnits should always be based on proof from LA_SpatialSource documents with LA_Points. After developing the country profile, still many technical design and implementation decisions have to be made during the conversion of country profile to technical model: identifiers (PK, FK), time stamps, versioning, indexing, clustering, multiplicity of attributes and relationships, constraints, derived attributes and the earlier mentioned 2D/3D geometry/topology structure.
Future work includes, besides developing the initial new conceptual model (country profile), also assessment of the proposed model before taking further implementation decisions. For this purpose a prototype system should be developed in order to discover the possibilities and limitations of the conceptual model. Experience from the prototype development will be used to further improve the conceptual model, before actual implementation. The steps in developing this prototype include:

1. deriving the technical model (Oracle, Esri frontend) from the conceptual model: from UML diagram, to database tables SQL DDL scripts for data storage (and/or XML schema for exchange format according to LandXML/ InfraGML, CityGML, BIM/ IFC),
2. convert some (and/or create) sample SOI/LR/ILA data into the newly proposed model: this covers both spatial and non-spatial data, and should also include selection for the exemplary 3D cases, which are to be supported by the future 3D Cadastre, and
3. develop frontends (possibly based on Esri) to view and edit for professional desktop access, and also develop an appropriate web-interface for SOI/LR/ILA data access.

In addition to the various technology aspects, it is important to consider the legal and organizational aspects. In the organizational setting of Israel with licensed surveyors (responsible for the creation the new 2D and 3D representations of parcels), it is crucial to develop regulations/formats for digital 3D mutation plans. This will then enable more automated validation to check correctness (e.g. non-overlapping issues). 3D cadastral registration is part of whole 3D spatial development life cycle in 3D consisting of many steps of which the order may differs per country (van Oosterom 2013): from the development and registration of zoning plans in 3D, to the dissemination, visualization and use the spatial units (parcels) in 3D. This aligns well with the goals of the recently started Rainbow project in Israel with goals to realize a unified property database (distributed via SDI), and on top of this a Location Based Business Intelligence (LBBI) system to exploit this data; see Figure 8. As the LADM covers data from various government parties, it can very well support the digital collaboration within the Israeli government. Various organizations are sources of different types of RRRs with either: own geometry or references cadastral parcels.

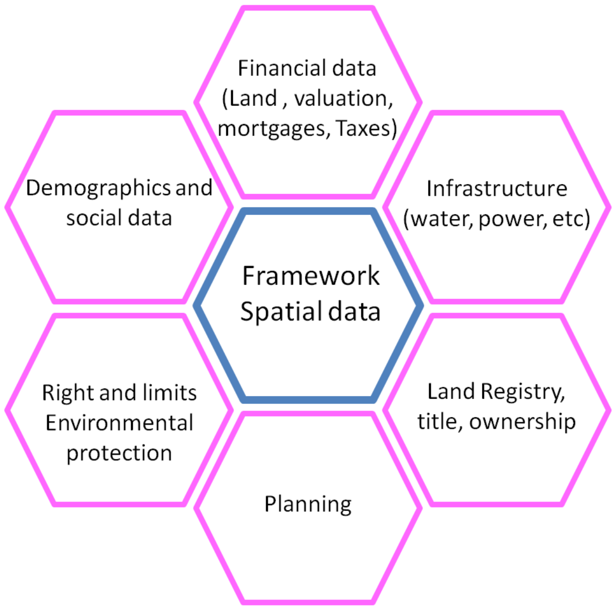

Figure 8. Various data sources in the Rainbow project in the spatial data framework

This paper discussed the 3D Cadastre developments by extending the parcels (LA_SpatialUnits) and using the 'standard' history/ versioning approach of LADM's VersionedObject for the temporal dimension with DQ_Quality (accuracy, scale) as separate attribute for quality related aspect. The fundamental question arises should these 3D space, time and scale 'attributes' be treaded separately, or is it worthwhile to deeply integrate these in a single higher dimensional representation as suggested in (van Oosterom and Stoter, 2010). These topics are related to the recently started research "5D Cadastral GIS project (5DMpLIS)" by an Israel-Greek consortium.

REFERENCES

Moshe Benhamu and Yerach Doytsher (2001). Research toward a multilayer 3D Cadastre: Interim results. In proceedings International Workshop on 3D Cadastres, 2001, Delft, pp. 35-51.

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

Moshe Benhamu (2006). A GIS-Related Multi Layers 3D Cadastre in Israel. In proceedings XXIII FIG Congress, Munich, Germany, October 8-13, 2006.

Alisa Caine (2009). Spatial Rights Legislation in Israel - A 3D Approach. In proceedings FIG Working Week 2009, Eilat, 14 p.

DNRM (2013). Department of Natural Resources and Mines, State of Queensland. Registrar of Titles Directions for Preparation of Plans. Website visited 28 February 2014, http://www.dnrm.qld.gov.au/__data/assets/pdf_file/0011/97319/directions-for-the-preparation-of-plans.pdf

Joseph Forrai and Gili Kirschner (2001). Transition from two-dimensional legal and cadastral reality to a three-dimensional one. In proceedings International Workshop on 3D Cadastres, 2001, Delft, pp. 9-23.

Joseph Forrai, Sarit Murkes, Larisa Voznesensky and Michael Klebanov (2004). Development of a Better Cadastral Practice at the Survey of Israel. In proceedings FIG Working Week 2004, Athens, Greece, May 22-27, 2004.

Armi Grinstein (2001). Aspects of a 3D Cadastre in the new city of Modi'in, Israel, in proceedings International Workshop on 3D Cadastres, 2001, Delft, pp. 25-33.

ISO-TC211 (2012). Geographic information – land administration domain model (LADM). ISO/IS 19152.

Mohsen Kalantari, Abbas Rajabifard, Jill Urban-Karr and Kenneth Dinsmore (2013). Bridging the Gap between LADM and Cadastres. In proceedings 5th Land Administration Domain Model Workshop, September 2013, Kuala Lumpur, pp. 447-464.

Sudarshan Karki, Rod Thompson and Kevin McDougall (2013). Development of validation rules to support digital lodgement of 3D cadastral plans In: Computers, Environment and Urban Systems, Volume 37, 2013, 12 p.

Baris M. Kazar, Ravi Kothuri, Peter van Oosterom and Siva Ravada (2008). On Valid and Invalid Three-Dimensional Geometries. In: Advances in 3D Geoinformation Systems, Springer, 2008, Chapter 2, pp. 19-46.

José Miguel Olivares García, Luis Ignacio Virgós Soriano and Amalia Velasco Martín-Varés (2011). 3D Modeling and Representation of the Spanish Cadastral Cartography. In proceedings 2nd International Workshop on 3D Cadastres, 16-18 November 2011, Delft, The Netherlands.

Peter van Oosterom (2013). Research and development in 3D cadastres. In: 3D Cadastres II, special issue of Computers, Environment and Urban Systems, Volume 40, July 2013, pp. 1-6.

Peter van Oosterom, Christiaan Lemmen and Harry Uitermark (2013). ISO 19152:2012, Land Administration Domain Model published by ISO. In proceeding FIG Working Week 2013, Abuja, Nigeria.

Peter van Oosterom, Jantien Stoter, Hendrik Ploeger, Rod Thompson and Sudarshan Karki (2011). World-wide Inventory of the Status of 3D Cadastres in 2010 and Expectations for 2014. In proceedings FIG Working Week 2011, Marrakech, 21 p.

Nurit Peres and Moshe Benhamu (2009). 3D Cadastre GIS - Geometry, Topology and Other Technical Considerations. In proceedings FIG Working Week 2009, Eilat, 14 p.

Queensland Government (1994). Land title act. Reprint 10A, Website visited 28 February 2014, www.legislation.qld.gov.au/LEGISLTN/CURRENT/L/LandTitleA94.pdf.

Haim Sandberg (2001). Three-dimensional division and registration of title to land: Legal aspects. In proceedings International Workshop on 3D Cadastres, 2001, Delft, pp. 201-209.

Haim Sandberg (2003). Three-Dimensional Partition and Registration of Subsurface Space. In: Israel Law Review, Volume 37, 1, 2003, pp. 119-167.

Haim Sandberg (2014). Developments in 3D horizontal land sub-division in Israel: Legal and urban planning aspects. In abstract book Planning, Law and Property Rights (PLPR) 2014 Conference, Technion, Haifa, Israel, 10-14 February 2014, page 75.

Uri Shoshani, Moshe Benhamu, Eri Goshen, Shaul Denekamp and Roy Bar (2004). Registration of Cadastral Spatial Rights in Israel – A Research and Development Project. In proceedings FIG Working Week 2004, Athens, Greece, May 22-27, 2004.

Uri Shoshani, Moshe Benhamu, Eri Goshen, Shaul Denekamp and Roy Bar (2005). A Multi Layers 3D Cadastre in Israel: A Research and Development Project Recommendation. In proceedings FIG Working Week 2005 and GSDI-8.

Jantien Stoter, Hendrik Ploeger and Peter van Oosterom (2013). 3D cadastre in the Netherlands: Developments and international applicability. In: 3D Cadastres II, special issue of Computers, Environment and Urban Systems, Volume 40, July 2013, pp. 56-67

Rod Thompson and Peter van Oosterom (2012). Validity of Mixed 2D and 3D Cadastral Parcels in the Land Administration Domain Model. In: P. van Oosterom, R. Guo, L. Li, S. Ying, S. Angsüsser (Eds.); Proceedings 3rd International Workshop 3D Cadastres: Developments and Practices, October 2012, Shenzhen, pp. 325-342.

Rod Thompson (2013). Progressive Development of a Digital Cadastral Data Base. In proceedings 5th Land Administration Domain Model Workshop, September 2013, Kuala Lumpur, pp. 447-464.

Natalia Vandysheva, Sergey Sapelnikov, Peter van Oosterom, Marian de Vries, Boudewijn Spiering, Rik Wouters, Andreas Hoogeveen and Veliko Penkov (2012). The 3D Cadastre Prototype and Pilot in the Russian Federation. FIG Working Week 2012, May 2012, Rome, 16 p.

Shen Ying, Renzhong Guo, Lin Li, Peter van Oosterom, Hugo Ledoux and Jantien Stoter (2011). Design and Development of a 3D Cadastral System Prototype based on the LADM and 3D Topology. In: P. van Oosterom, E. Fendel, J. Stoter, A. Streilein (Eds.); Proceedings 2nd International Workshop on 3D Cadastres, November 2011, Delft, pp. 167-188

BIOGRAPHICAL NOTES

Yaron Felus holds a BS from Ben-Gurion University, Israel (Electrical and Computer Engineering), a M.S. from the International Institute for Geo-Information Science and Earth Observation, Netherlands (Geomatics), and both M.S. and Ph.D. from the Ohio State University (geodetic science). He is a Professional Surveyor in Michigan, USA and completed his surveying education in the Israeli Technion to become a Licensed Surveyor in Israel.

Shimon Barzani was born in 1968. He holds a BSc from Technion University, Israel (Civil Engineering and Geodesy). He is a Professional Surveyor in Israel. He is currently Director, Mapping Technologies and Customers Support Department at The Survey of Israel.

Alisa Caine was born in 1960. LLB (Hebrew University), LLM (Hebrew University). Member of the Israel Bar Association since 1984. Since 2000, employed at the Israeli Ministry of Justice. Currently serves as the National director of the Land Registry.

Nimrod Blumkine has a B.sc in Engineering from Ben-Gurion University and an MBA majoring in Operations Research from the Tel-Aviv University. He had led several national level Information systems and data modelling programs for large GOs, as well as software related R&D projects. Currently he is responsible for the data program at the Israel Land Authority.

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'.

CONTACTS

Yaron Felus
The Survey of Israel
1 Lincoln St
Tel-Aviv
ISRAEL
Tel. +972 50 6225448
E-mail: felus@mapi.gov.il
Website: http://mapi.gov.il/en/Pages/default.aspx

Shimon Barzani
The Survey of Israel
1 Lincoln St
Tel-Aviv
ISRAEL
Tel.: +972 50 6247272
E-mail: shimon@mapi.gov.il
Website: http://mapi.gov.il/en/Pages/default.aspx

Alisa Caine
Ministry of Justice, Land Registry
POB 2560
Jerusalem
ISRAEL
Tel.: +972 2 5696122
E-mail: alisak@justice.gov.il
Website: http://www.justice.gov.il/mojeng

Nimrod Blumkine
Israel Land Authority
ISRAEL
Tel.: +972 54 4425450
E-mail: nimrodb@land.gov.il
Website: http://www.land.gov.il/Envelope/indexeng.asp

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