

# **A Multi Layers 3D Cadastre in Israel: A Research and Development Project Recommendations**

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**Key words:** Spatial Sub-Parcel, Spatial Parcel, Displacement Distances, Spatial Registration Plan

## **SUMMARY**

The multi layers 3D cadastre R&D project has been initiated and specified by the Survey of Israel (SOI). The R&D project started in September 2002 and had been carried out by a team of experts from several disciplines. The project has been successfully completed during August 2004. This R&D project was one of the steps undertaken by the SOI during the last 6 years concerning the efforts to replace the existing two-dimensional (2D) cadastral system by a three-dimensional (3D) one.

The principal objectives of the R&D project were to find geodetic, cadastral, planning, engineering and legal solutions, for utilizing above and below surface spaces, thus defining the characteristics of the future analytical, 3D and multilayer cadastre that will complement the existing 2D cadastre.

In recent years, the State of Israel has entered the post-industrial era, characterized by fast economic development driven by population growth, expanding economy and a rising standard of living. This is accompanied by the constantly increasing building density, primarily in the central areas of the country that are the preferred places for residence due to employment and commercial opportunities. Moreover, the growth in population, projected to rise from six millions today to nine million by 2020, accentuates the urgent need to find new solutions for building of public projects and new infrastructures in subterranean areas and above the existing surface constructions, while preserving the remaining open spaces. Therefore, Israel has a particular interest in the immediate exploitation of the spatial potential, especially in the central area of the country.

This paper introduces the recommendations of the R&D team for the immediate implementation of the 3D cadastre in Israel. The first steps to be taken by the Israeli government and parliament (“kneset”) are the modifications in the existing Land Law and the Planning and the Construction Law and their Regulations and also the modification of the Survey Regulations.

# A Multi Layers 3D Cadastre in Israel: A Research and Development Project Recommendations

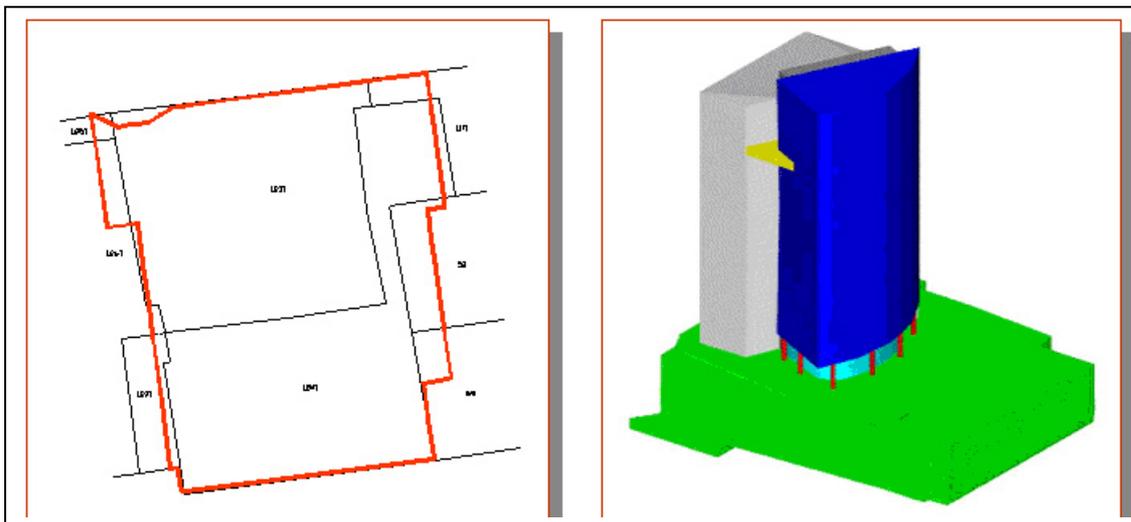
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## 1. INTRODUCTION

The existing cadastre and the Land Law (1969) do not provide a solution for multilayer activities related to land parcels (*Benhamu and Doytsher, 2001*). The existing cadastral system is based on Torrens principles (Registration of Title), is 2D, dealing only with surface properties. Under the Israeli Land Law, the property right in a land parcel, extends from the center of the earth and radially outwards into space, including all that is built or cultivated upon its surface. Therefore, there is a growing awareness of the necessity for finding a legal and a cadastral solution for registering rights of multilayer cadastral reality.

The Israeli government decided in 1999 and in 2000 to improve the efficiency of the land use. These decisions are pointing at the government's interest in implementing the multilayer cadastre. In order to carry out the government decisions, the SOI nominated a team of experts to examine a comprehensive solution, taking into account all the issues concerning the 3D cadastre.

The governmental decisions included orders to modify the laws and the conditions that will facilitate utilization of a land site for a number of uses, both above and below the surface. Following this, the government nominated two governmental commissions. The first one monitored the research work. The second examined the legal changes recommended by the R&D team in order to present them to the government at the end of the R&D project.

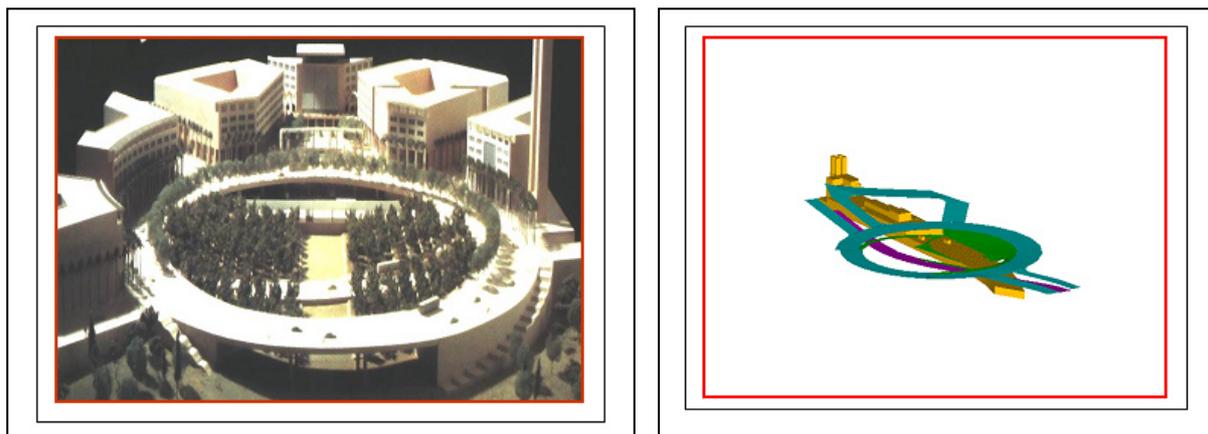


**Figure 1:** A multistory building – The land parcels regarding to the parking and a 3D model of the building and the parking

The objective of the 3D cadastre registration is to be achieved through a number of subsidiary objectives as follows:

- 3D Definition and registration of spatial parcels.
- Proposals for changes in the existing Land Law, the Planning and the Construction Law, considering the applicable engineering and planning constraints.
- Accumulation of the altimetric data to be added to the 2D cadastre, thus creating the 3D database.
- Solution to the management of analytical cadastral information, in 2D and 3D GIS environment.
- Establishment of an active computerized model of registration of rights to land in a spatial concept.
- Development of suitable software for the visualization of 3D cadastre.
- Modification of the Survey Regulations in order to facilitate registration of 3D cadastre.

The R&D project had been carried out by 5 experts from different disciplines: Cadastre, Geodesy, GIS, Law, Planning and Construction, Geology and Soil Engineering. The Ministry of Finance has approved a budget of approximately one million US\$ for the R&D project and for five pilot projects. One of the pilot projects is a multistory building in the center of Tel-Aviv that includes subterranean parking on several layers, which extends in the space of several parcels belonging to different owners (*Grinstein, 2003*) (see fig 1). The second one is in the center of a new town (called Modi'in), currently under development and construction, and includes four subterranean levels with different ownerships and planned for different purposes (a railway station, public park, bus terminal and a principal road) (*Grinstein, 2003*) (see fig 2). The other pilot projects (a Templar's tunnel, St. Andreas church and the "Knight Halls") are in the ancient town of Acre, which include two layers of buildings. The lower layer includes buildings and tunnels from the Crusader's ancient period and the upper layer-buildings from the Mameluke period, which serve even nowadays as residential structures, churches and mosques.



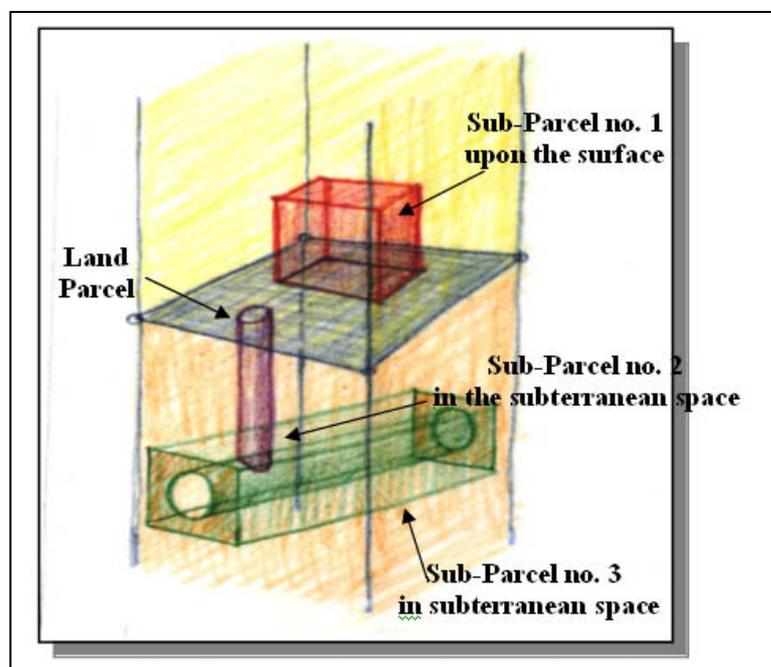
**Figure 2:** The town center of Modi'in –  
A 3D model and 3D presentation of the roads and the railway

The principal objective of these projects is the registration of rights to land in a complex composed of a number of structures, below and above the surface. This principal objective includes also several secondary objectives: construction of 3D models of the surface and the subterranean reality, definition of the spatial sub-parcels which envelope the physical objects in subterranean space, integration of spatial sub-parcels in order to produce a “spatial parcel” and production of a spatial registration plan. In all the pilot projects, the R&D team has prepared plans for 3D registration purposes, in accordance with the recommendations stated above. All these plans will serve as examples for 3D registration in the future.

## 2. FOUR ALTERNATIVES FOR THE SPATIAL REGISTRATION OF PROPERTY RIGHTS

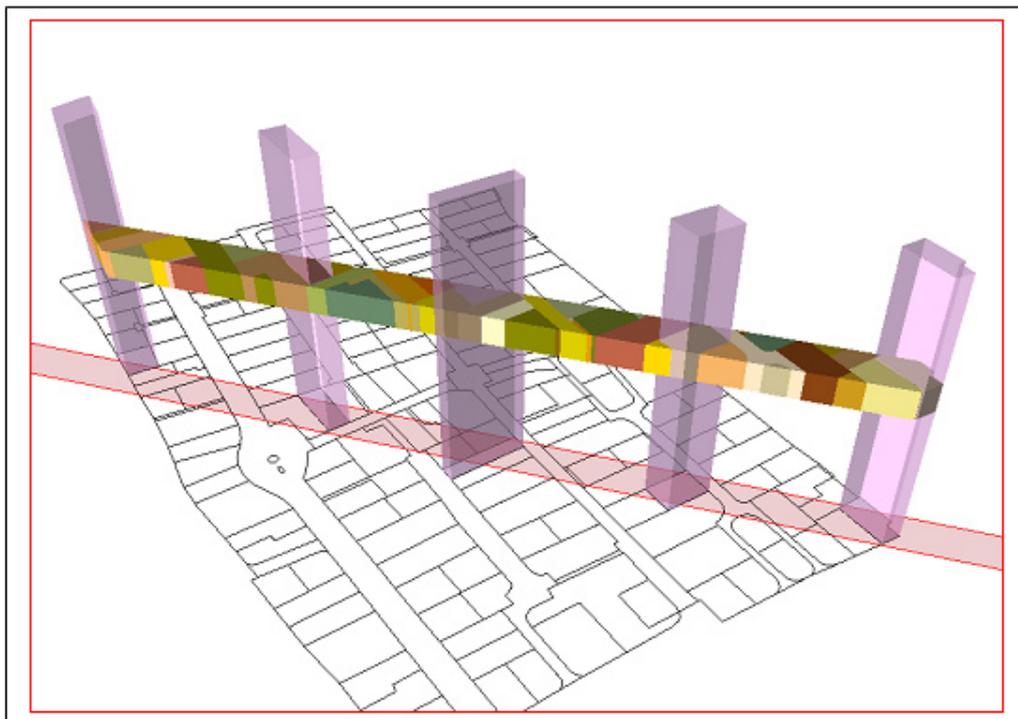
Under the Israeli Land Law, the property rights in a land parcel extend from the center of the earth and radially outwards into space, including all that is built or cultivated upon its surface. In order to practice the 3D exploitation potential by different interested parties, it is necessary to define a legal and cadastral solution capable of registering rights in a multilayer cadastral reality. In order to do so, the R&D team examined the following four alternatives:

- The Amended “Land Law” Alternative: The activities in the subterranean space and the air space will be possible by changing the extent of rights in a parcel of land, within the Land Law (*Benhamu and Doytsher, 2001*). The infinite extent of rights will be limited to a specified height above and/or depth below the surface of the parcel, within the applicable exploitation limits.



**Figure 3:** Spatial division into sub-parcels

- The Alternative of “Registration of Condominiums”: Since most condominiums consist of several apartments built mostly on top of each other, it is possible to refer to the condominium as a vertical sub-parcellation (*Benhamu and Doytsher, 2001*). This vertical sub-parcellation is due to coexistence of many different owners in the parcel's space and many different properties on the same parcel. The Registration of Condominiums by the Land Law governs the status of the rights of the several property owners on the same land site, and provides a legal solution of separate ownership on levels.
- The “Objects Registration” Alternative: This alternative consists of the establishment of an “objects registry” for spatial objects, totally separated from the existing land registration (*Benhamu and Doytsher, 2003*). The objects registry will deal only with spatial objects.
- The “Spatial Sub-Parcel” Alternative: This alternative provides a solution for the registration of spatial objects, not adjacent immediately to the registered surface parcel, whereas each one of those spatial objects is subject to defined rights and obligations (*Shoshani, Benhamu, Goshen, Denekamp and Bar, 2004*). The activities in the subterranean space and in the above-terrain space will be made possible through an allotment or expropriation of specific parts of the space included within the vertical boundaries of the surface parcel (see fig 3 and fig 4). This alternative of creating spatial sub-parcels has been selected by the R&D team, as the proposed solution for the registration of rights in space. The monitoring commissions approved the recommendation.



**Figure 4:** 3D Presentation of the spatial sub-parcels on the background of the existing land parcels

### 3. PRINCIPLES OF THE “SPATIAL SUB-PARCELS”

The principles, which guided the R&D team in formulating the solution to the spatial cadastral registration and its adoption to the existing cadastral reality, were to avoid infringement upon the existing system, as follows (*Shoshani, Benhamu, Goshen, Denekamp and Bar, 2004*):

- The spatial registration will be achieved by sub-dividing the surface parcel space into spatial sub-parcels (see fig 5). The definition of the surface parcel will remain unchanged. Any project established in one of the spatial sub-parcels (above or below the surface) will be bounded and defined stereometrically by a final 3D outline and its volume. A spatial project, which extends above or below a number of surface parcels, will be thus subdivided into spatial sub-parcels, in accordance with the existing surface parcels. If required, it will be possible to consolidate the spatial sub-parcels, within a registration block, into one spatial parcel.
- The Title Rights to the surface parcel will be preserved according to the existing definition of the surface parcel as extending infinitely above and below the surface. However, the spatial sub-parcel will be defined as a finite volumetric object, subtracted from it.

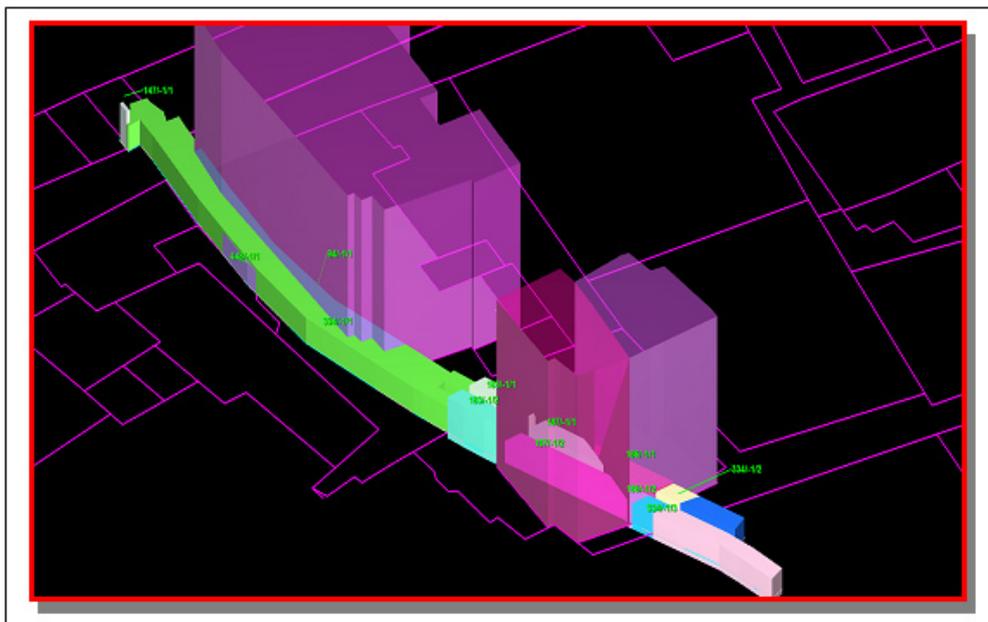


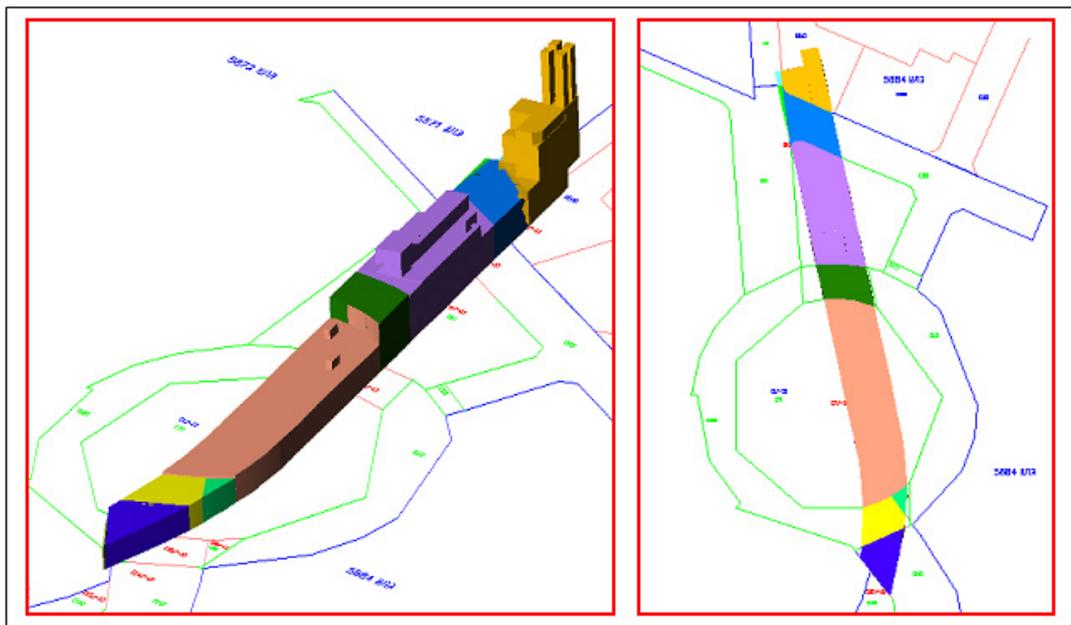
Figure 5: The 'Templer's tunnel in the old town of Acre - 3D Presentation of the spatial sub-parcels on the background on the existing land parcels

- The spatial sub-parcel will be included in the existing registration block as a part of the surface parcel. The existence of spatial sub-parcel will be noted also in the Title Register. The Register will include the 3D definition of the spatial sub-parcel. In the case of consolidation of several spatial sub-parcels into one spatial

parcel, this spatial parcel will be registered separately in the Register and in the registration block (see fig 6).

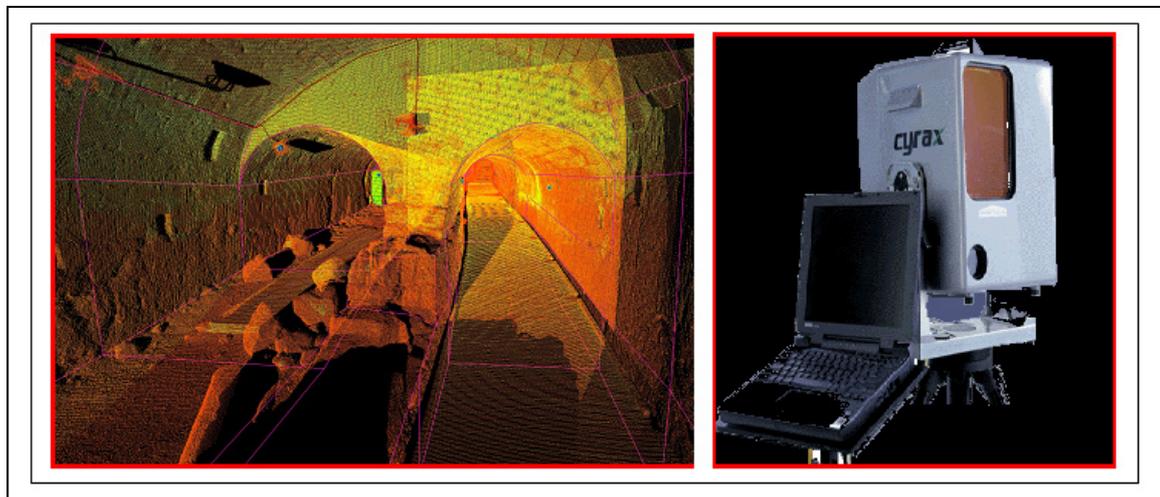
The proposed solution for the cadastral spatial registration will be realized on the basis of the following recommendations of the R&D team (*Shoshani, Benhamu, Goshen, Denekamp and Bar, 2004*):

- Preservation of the Rights to Property: No infringement of the rights to property, except for proper purposes and limited to the minimal required extent.
- Setting off Distances: The stability of the existing structures built on the surface of the earth, will be achieved by setting off distances to them and to the spatial sub-parcel as well, imposed by engineering considerations.
- Continuity of the Existing Registration Method: Allowing extension and adaptation of the existing registration system to the new spatial cadastral reality without infringement upon the system itself. Necessary amendments will be made in the Land Law, Planning and Construction Law and the Survey Ordinance.
- Subterranean Registration Following Construction: In many cases, the underground construction does not conform exactly to the planning, especially in cases of unexpected technical difficulties. Therefore, the final registration of the subterranean sub-parcels will usually be made only after the project has been completed, measured “as-made” and registered accordingly. During the planning and construction stages only a warning note will be registered.



**Figure 6:** 3D and 2D Presentation of the spatial parcel and the spatial sub-parcels on the background on the existing land parcels – The railway station in the town center of Modi'in in a 3D model and 3D presentation of the roads and the railway

- GIS Land Management: The future cadastre will be incorporated into the national GIS system and will be managed by GIS means. This will result in a more efficient planning, exploitation and management of all three spaces of the land.
- A Soft Copy Combined with a Hard Copy: All maps and plans will be based on a digital database, as vectors, GIS and digital maps. The spatial activities will be shown three-dimensionally (perspective and sections) in a plane projection on the computer monitor. A plotted map (hard copy) will also be produced in the format similar to a regular block registration map, on which the spatial activities will be detailed on separate plans at different levels, with the aid of colors and conventional signs, similarly to the maps presently in use. The existing surface division will be displayed as a background to the spatial subdivision.
- The Spatial Geodetic Technology Feasibility: The state of the art methods (Laser scanning) and existing geodetic technologies have been experimented with in the Tel-Aviv, in Modi'in and in Acre sites, and have been found feasible for application in the production of registration plans both below and above the surface (see fig 7).



**Figure 7:** The Templers' tunnel in the old town of Acre – laser scanning and the laser scanner

#### 4. DEFINITION OF TERMS

- Hereafter is a list of selected terms used in this article.
- Registration Block: A defined area, out of a settlement's land, that include a parcel or number of parcels, Spatial Sub-Parcel or number of Spatial Sub-Parcels, spatial parcel or number of spatial parcels. This defined area serves as a surveying and registration unit.
- Parcel: A piece of land, which is a part of a Registration Block, registered in the Land Registration Books and defined by its shape, its boundaries lengths and its area, in "First Registration" or registration according to the "Land Registration

Ordnance” or in its mutation prepared according to the Survey Ordnance – 1928 or its regulations.

- Spatial Parcel: A volumetric registration unit, which is a part of a Registration Block, defined in above or below surface and created by consolidation of several spatial sub-parcels, defined in the boundaries of the Registration Block.
- Displacement Distances: The distances between the project itself and the outer envelope, displaced from the project, by engineering stability, safety and ecological considerations. These “displacement distances” will be specified by a planning authority in a document describing the relationships between the project and its environment as far as the influence of the project and its operation is concerned.
- Spatial Lot: A spatial volumetric land unit, defined in a multi layers town planning plan, taking into account the Displacement Distances and is a part of a parcel, before it is registered as a spatial sub-parcel in the Land Registration Books whether construction is permitted there or not.
- Subterranean Space: The definition of a space’s outline in the subterranean areas, according to a town-plan, without taking into accounts the buildings and cultivated areas upon the surface.
- Above Terranean Space: The definition of a space’s outline above terrain areas, according to a town-plan, without taking into accounts the buildings and cultivated areas upon the surface.
- Spatial Physical Object A Physical object defined in subterranean space or in above terrain space, included in spatial sub-parcel. Its outer boundaries are included in the spatial sub-parcel according to the displacement distances.
- Spatial Registration Plan: 3D cadastre registration plan is a digital, 3D and multi-spaced.
- Spatial Sub-Parcel: A volumetric registration unit, defined in above or below surface and which is included within the vertical boundaries of the surface parcel.

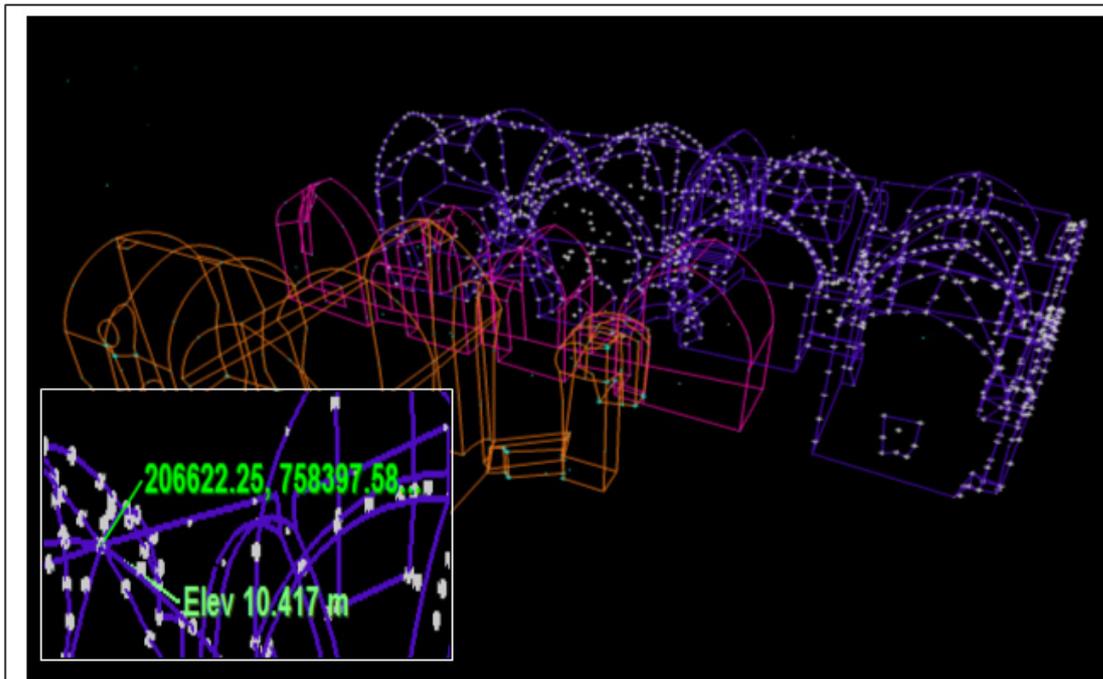
## 5. THIRD DIMENSION – THE DIMENSION OF HEIGHT

The delineation of surface parcels, spatial sub-parcels and spatial parcels that are vertically layered, requires a spatial description, including data defining the horizontal and vertical boundaries between these units. The ability to present spatial characteristics of land parcels will permit a better definition of cadastral spatial subdivision. The three dimensional presentation will provide better means for inspection and analysis of data, than the existing 2D one (*Shoshani, Benhamu, Goshen, Denekamp and Bar, 2004*).

The principal problem in managing a multilayer cadastre is how to register the 3D properties of objects. The ideal solution would be for the boundaries of properties of parcels to be managed in three-dimensions, with each point on the boundary of a parcel defined by  $x$ ,  $y$ , and  $h$  coordinates. Complete 3D registration will enable accurate registration, management and definition of the multilayer reality.

The following options were examined as part of the research:

- Two dimensions, without any height information (corresponding to the current reality only).
- Using "below the surface" and "above the surface" tags or "above surface", "below surface" and "surface", without any specific measurements.
- Only a 2.5 dimensions: The 2.5D is an intermediate situation between 2D and 3D (Benhamu and Doytsher, 2003). This model employs the function  $z = f(x,y)$ , where each  $x$  and  $y$  has one unique height. In this model, linear objects are displayed fairly well, but a problem arises in displaying 3D nonlinear surfaces. For most spatial objects, which have several points with identical coordinates but with different heights, this option is inapplicable.



**Figure 8:** 3D Model compilation – The St. Andreas Church in the old town of Acre

## 6. THIRD DIMENSION – THE R&D TEAM RECOMMENDATIONS

- The parcels, the spatial sub-parcels and the spatial parcels will be defined analytically in 3D. Every boundary point in the circumference of the surface parcel and every boundary point in the envelope of the spatial sub-parcel and the spatial parcel will be defined by the  $x$  and  $y$  coordinates in the new Israeli grid and their orthometric heights above or below sea level.
- The  $x$ ,  $y$  and  $h$  coordinates, which define the border points in the envelope of the spatial sub-parcel and the spatial parcel will be used as legal coordinates. The  $x$  and  $y$  coordinates, which define the boundary points in the surface parcel will be

legal while the definition of the heights of the surface parcel will serve only for information purposes.

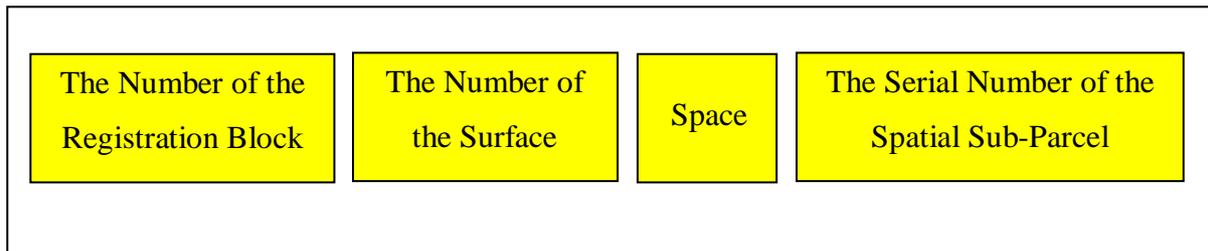
- In those surface parcels, where there are subterranean or above terrain spatial physical projects, the registration books will include information about average height, maximum height, minimum height of the surface parcel. This information, though registered, will serve for information purposes only and not as legal information.
- Changes in the heights of the surface parcel will not demand changes in the registered heights. Nevertheless, while preparing spatial registration plan, the heights in the registration books will be updated.
- The density of the boundary points to be measured in the envelope of the spatial sub-parcel and spatial parcel, is to be considered, taking into account how close or far is the spatial physical object from it's envelope.
- The 3D analytical definition of the spatial sub-parcels border and the spatial parcels border will be based on in or out survey of the spatial physical object together with parameters of its design and the displacement distances fixed in the town planning plan.
- In order to define mathematically the envelope of the spatial sub-parcels and the spatial parcels it is enough to measure the inner part of the spatial physical object. Even this measurement must not be very dense.

## **7. NUMBERING OF SPATIAL PARCELSS IN THE 3D CADASTRE**

Today, the whole State of Israel is sub-divided into Registration Block Plans (about 20,000 at all). Every Registration Block Plan is sub-divided into parcels. The identification number of the parcel is a combination of the number of the Registration Block Plan and the serial number of the parcel in the Registration Block Plan. Thus, the identification of a parcel is unique and no number of a parcel can be repeated. Whenever a mutation is prepared, concerning parcellation and/or consolidation of a parcel or parcels, the new parcels created in the mutation are given new serial numbers, beginning with the next number after the last existing parcel number in the Registration Block Plan.

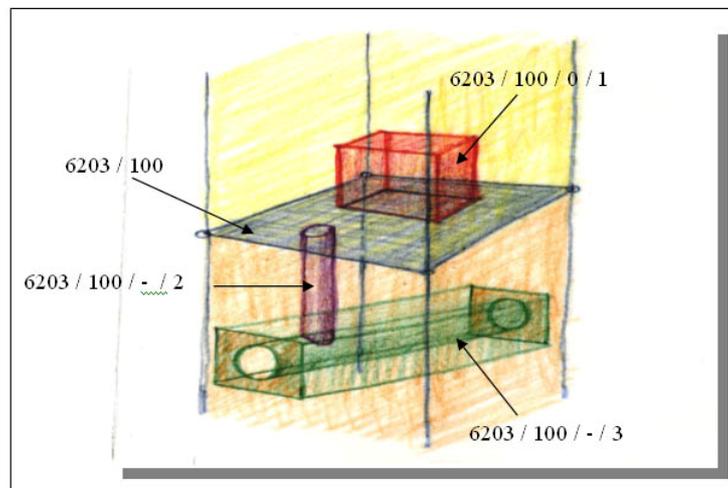
The R&D team examined the following three alternatives for the numbering of the spatial parcels in the 3D cadastre:

- Sub-divided of the subterranean space and the above terrain space into Registration Block Plans, which coincide to the existing surface Registration Block Plans. The Spatial Registration Block Plan will carry the same number as the Surface Registration Block Plan plus a special space code. The numbering of spatial parcels in the Spatial Registration Block Plan will be serial beginning with number one and on.
- A surface parcel and a spatial parcel altogether, will get a serial and unique identification number. The use of this identification number in a computerized Land Information System will enable the user to get all the information concerning the parcel quoted.



**Figure 9:** The identification number of spatial sub-parcel

- The recommended alternative by the R&D team for the numbering of spatial parcels, is as follows:
  - The existing sub-division of the state area into Registration Block Plans and the sub-division of every Registration Block Plan into surface parcels will be preserved.
  - The existing numbering method will be preserved.
  - Every spatial parcel will be number according to existing number method that is will be numbered by a number, one after the last number of parcel in the existing Registration Block Plan.
  - The identification number of the spatial sub-parcel will include the following: The number of the surface parcel, space code (“-“ – subterranean space, “+” - above terrain, “0” - land surface) and a serial number of the spatial sub-parcel in the surface parcel ownership space (see fig 9 and fig 10).



**Figure 10:** Example of the recommended alternative for the numbering of spatial sub-parcels

## 8. SUMMARY

Most of the existing cadastral systems are 2D and deals only with properties on the surface of the land. The existing cadastral systems, due to being surface and 2D, are unsuitable, as is, for the multilayer reality that has evolved in recent decades. In order to facilitate the continued establishment of engineering projects below and above the surface, and particularly to enable the registration of properties that are not on the surface, it is necessary to amend the legislation and define a new multilayer and 3D cadastral model.

The multi layers 3D cadastre R&D project was one of the steps undertaken by the SOI during the last 6 years concerning the efforts to replace the existing two-dimensional (2D) cadastral system by a three-dimensional (3D) one. It is worthy to note, that this R&D project is one of the first of its kind, both in Israel and worldwide. The final results of the R&D project, will hopefully lead to the realization of the 3D cadastre in Israel and will assist the authorities in the transition period.

## ACKNOWLEDGMENT

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## **BIOGRAPHICAL NOTES**

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