A GIS-Related Multi Layers 3D Cadastre in Israel

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Key words: spatial data infrastructures (SDI), spatial sub-parcel, spatial parcel, multi layer data model

SUMMARY

The general density of the population in central and northern parts of Israel (some 480 inhabitants per square kilometer) is higher then in Germany, Belgium, Japan or the Netherlands. Moreover, during the past decade the population increased from six millions to nine million by 2020, and 13 million in 2050. To enable continued extensive land development, new options need to be found for urban development through more effective utilization of space both above and below the ground surface (as well as beneath the sea).
For promoting the multi-layer-use of land and its registration in strata, a multi layers 3D cadastre R&D project has been initiated and specified by the Survey of Israel (SOI) and had been carried out by a team of 6 experts from several disciplines. The project has been successfully completed during August 2004. 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. 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.
This paper introduces the creating spatial sub-parcels, as the proposed solution for the registration of rights in space and the recommendations for the immediate implementation of the 3D cadastre in Israel.

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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. In the current legal status (in Israel as in most of the countries), the right of ownership in a parcel radiates to the center of the earth except for specific laws (regarding water, oil, mines, minerals etc.) and to the sky without preventing the passage in the sky. As can be seen, the legal definition of the rights is open to further limitations. In reality, there are many restrictions to the rights of ownership, some which are obvious and formulated and some that are fuzzy due to difficulties in defining the connected area and describing it in the registration.

As to structures under the surface, in many cases, the method of registration is using easement for the benefit of the state. This process often involves legal acts of expropriation and includes legal disputes and paying of compensation. The easement is registered after the legal proceedings and before the completion of the construction. Therefore, the information is not specified and, in many cases, is lacking the 'technical' or accurate and 'real' ("as made") details.

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: "the Minister of Justice … is to submit proposed guidelines for implementing and amending legislation with the aim of facilitating more efficient land use, including subterranean space, and integrating several infrastructures and various applications in a single locality". The decisions also decree that "a solution for ownership problems, registration of rights and surveying…" should be developed also for underground space. Another government resolution in mid 2000 is specifically dedicated to the necessity of practical solution of registration of rights in three dimensions.

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. Development of the 3D cadastre involves solving technological-geodetic problems on the one hand, and solving the legal aspects on the other hand. From the scientific and technological standpoint, the principal challenge in developing a three-dimensional multi-layer cadastre lies in gathering, processing and managing the three-dimensional data. The third dimension, which does not appear in the current two-dimensional cadastre, necessitates development of new spatial models for managing the subsurface information and linking it to the surface information. The main tasks in the process of defining and establishing the 3D cadastre are:

- Digital version of the existing 2D graphical cadastre.
- Complementing 2D cadastre with elevation data.

- Measurements and/or data processing and mapping in 3 dimensions.
- Analytical connection between subsurface-, surface- and above-surface units of property.
- A model for global, 3D cadastre database relating to the NGIS environment.
- Visualization of the 3D cadastre database.
- Documentation of the whole 3D cadastre procedure.
- A proposal for spatial parcels registration procedure.
- Proposals for changes in the existing Land Law, the Planning and the Construction Law, considering the applicable engineering and planning constraints.
- Establishment of an active computerized model of registration of rights to land in a spatial concept.
- Modification of the Survey Regulations in order to facilitate registration of 3D cadastre.

2. THE CADASTRE IN ISRAEL

Israel, as many other countries, has a statutory division of land - the cadastre. Cadastral mapping began in Israel in 1926, based on Torrens (registration of titles) method, with the land unit and its area defined based on official surveying and mapping carried out by the State and linked to the national coordinate grid system. In similar to mapping, which over the recent decades has been gradually undergoing a transition from the graphic sphere to the digital sphere, the cadastre in Israel is now also in transition from the analogue era to the digital era. The changes instituted thus far, and those expected in the cadastre in the future, can be classified into four stages: Analogue (conventional) cadastre, Graphic (computerized) cadastre, Analytical cadastre and Three-dimensional multi-layer cadastre.
In the current analog cadastre in Israel (completed over 95% of the country) each administrative unit (village, local municipality, etc.) is divided into registration blocks, with each block divided into parcels. Measurement results are recorded in field books and used to determine the boundaries of the block and the parcels on a field plan sheet. The current cadastre in Israel is therefore a "graphic" cadastre in "analogue" form.

In the late 1980s, the Survey of Israel started preparations for the GIS/LIS era. All cadastral blocks (paper maps) are converted into digital form and are entered into the computerized GIS database. The graphic inputting of the analogue block maps is carried out according to defined specifications, primarily: scanning of the graphic material, automatic vectorization of the scanned raster, manual completing and graphic editing by operators (technicians, draftsmen). Within this framework of treating the cadastral data (a project in advanced stages, nearing completion), the graphic quality and accuracy of the blocks is preserved - and therefore the database that is created does not constitute a cadastral statutory validation for the borders of parcels and blocks. According to the Israeli surveying regulations, the renewal of cadastral boundaries is to be performed according to the original surveying data (field books) and not according to the graphic map.

The analytical cadastre may be considered as the modern alternative to the traditional cadastre (analogue or graphic/computerized). In the analytical cadastre, every geometric entity, point, line and area, is determined digitally by the State plane coordinate system. The coordinates of each parcel turning point will constitute the evidence for its position and enable its location or marking without requiring physical markings in the field. Thus, analytical cadastre data constitute a spatial information system of data on the statutory division of land.Obtaining digital mapping data for establishing the analytical cadastre creates a bottleneck in establishing the cadastral information system. New measurement of all land borders could provide a radical solution of the problem.

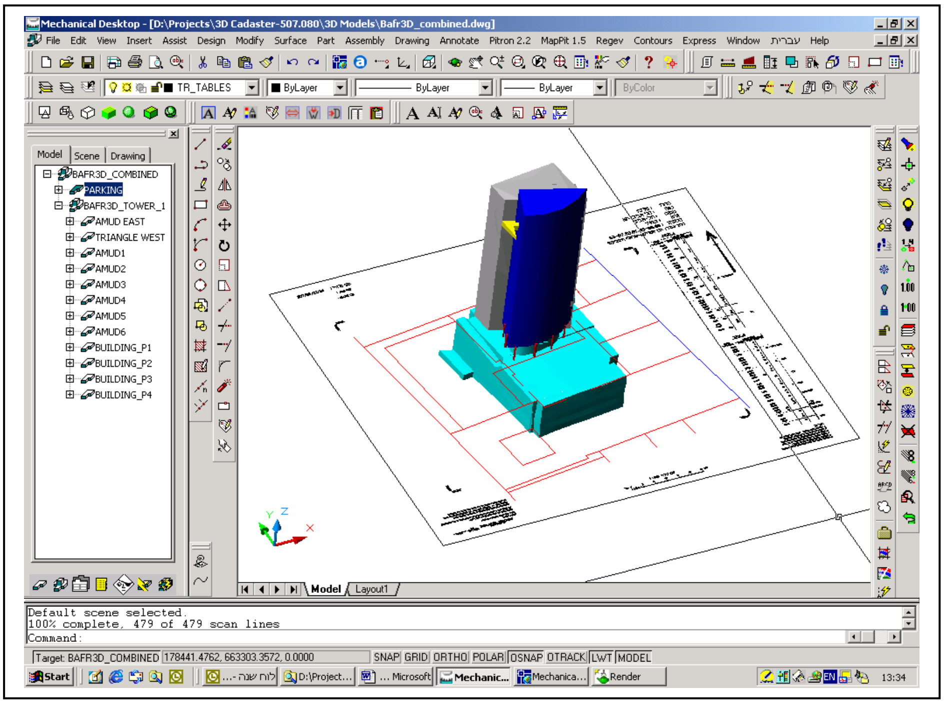

Figure 1: A multistory building – The land parcels regarding to the parking and a 3D model of the building and the parking (*By courtesy of Mr. Ronen Grinstein).*

3. A MULTI LAYER 3D CADASTRE – CHARACTERISTICS AND PROBLEMS

The significance of the future cadastre has been examined in recent years by many researchers, among these (Campbell and Hastie, 1998), (Gisiger, 1998), (Guillet, 1998), (Kaufman and Steudler, 1998), (Pratt, 1998) and (Tulloch, Niemann and Epstein, 1996a,b). Most of those dealing with this subject agree that the future cadastre will be analytical, three-dimensional (3D), multilayer, and that in similar with the current 2D cadastre, it will be concerned with land, law and people. The future cadastre will form fully comprehensive, methodical and updated documentation of private and public rights, ownership, land use and restrictions applicable to real estate in the various spaces. The 3D cadastre will determine the location of the parcel in space and its 3D boundaries and serve the legal and physical objectives, while also being utilized for basic mapping, planning land use and spatial environmental planning (as illustrated by figure 1).

Development of the 3D cadastre involves solving technological-geodetic problems on the one hand, and solving the legal aspects on the other hand. From the scientific and technological standpoint, the principal challenge in developing a three-dimensional multi-layer cadastre lies in gathering, processing and managing the three-dimensional data. The third dimension, which does not appear in the current two-dimensional cadastre, necessitates development of new spatial models for managing the subsurface information and linking it to the surface information. The main tasks in the process of defining and establishing the 3D cadastre are: Developing three-dimensional models of the surface and the subterranean reality, in respect to the cadastre; 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.

The Survey of Israel (SOI) is the governmental agency responsible for the whole cadastral surveying and mapping procedures in the country, including the changes in the existing cadastral status. Neither cadastral block maps, nor registration plans are judicially valid before the final approval of the SOI. This embracing cadastral responsibility of the SOI is undoubtedly extended to the third dimension.

4. 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 following five alternatives examined: The amended "Land Law" alternative, The alternative of "Registration of Condominiums", The "Benefit Commitment" alternative, The "Objects Registration" alternative and The "Spatial Sub-Parcel" alternative.

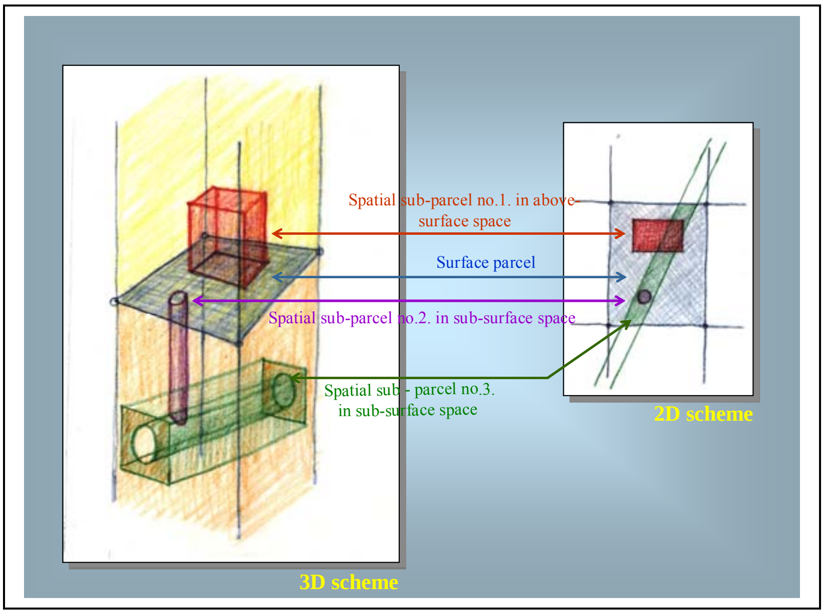

Figure 2: Spatial division into sub-parcels.

The alternative of creating spatial sub-parcels has been selected as the proposed solution for the registration of rights in space. 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 (Shoshani, Benhamu, Goshen, Denekamp and Bar, 2004) .

The spatial registration will be achieved by sub-dividing the surface parcel space into spatial sub-parcels (as illustrated by figure 2). The definition of the surface parcel will remain unchanged. Any project established in one of the spatial sub-parcels (above or bellow the surface) will be bounded and defined stereometricaly 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 (as illustrated by figure 3).

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

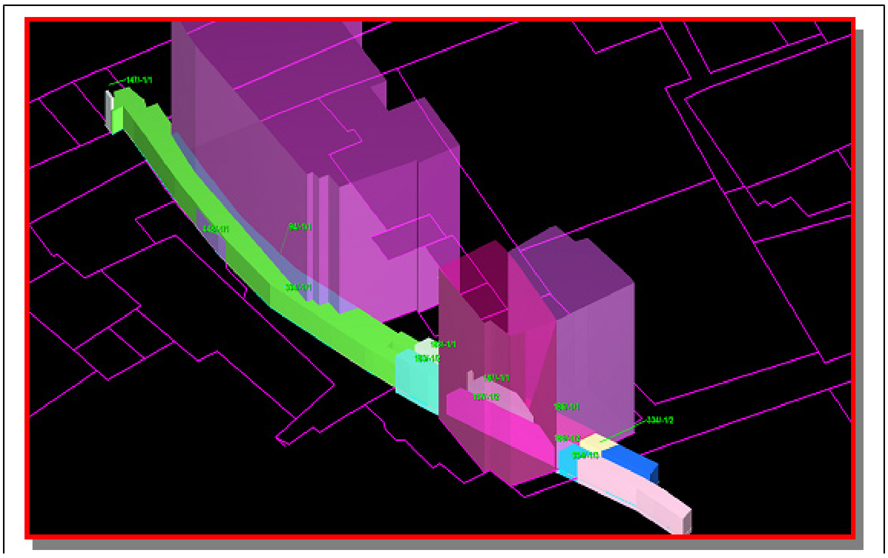

Figure 3: The Templer's tunnel in the old town of Acre - 3D Presentation of the spatial sub-parcels on the background on the existing land parcels (*By courtesy of Mabat – 3D Technologies ltd.).*

5. A 3D CADASTRAL DATABASE

One of the first stages in the transition from the traditional cadastre to the analytical and multilayer cadastre, is establishing a cadastral database of the current data, at a level that will facilitate reconstruct of boundaries, reparceling, etc. (Jones, Rowe, and Kentish, 1999).
The future 3D 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. 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 (as illustrated by figure 4).

6. SPATIAL INFORMATION MANAGEMENT

At present, the SOI's database of the land management information system consists of the one and only cadastral layer, two-dimensional, continuous, representing all land registration blocks and parcels. The 3D cadastre will require solutions for managing and organizing 3D and multilayer information. Four models have been examined:
<u>Layer Data Model</u>: Organizing multilayer information in layers by subject rather than by space, thus including geospatial objects from all layers. This data model will be suitable for the future multilayer reality where most activity will still be conducted on land. Including the multilayer objects in the surface layer will make it possible for the user to discover the multilayer relations between objects.

<u>Multilayer Data Model</u>: Information on multilayer objects will be organized in three cadastral layers, a layer for each space (surface, below surface, above surface). This solution is appropriate for the existing data model in most GIS systems. Moreover, it permits multilayer analyses with the tools available in the existing 2D GIS systems. The principal advantage of this data model lies in that it preserves the current surface cadastre layer.

<u>Object Oriented Database</u>: Organizing information on the object, rather than the layer level, so that the spatial property would be defined as an object and the information database would not include any one single information level. The objects will be classified into three spaces, with each object being assigned a spatial and chronological identity number.

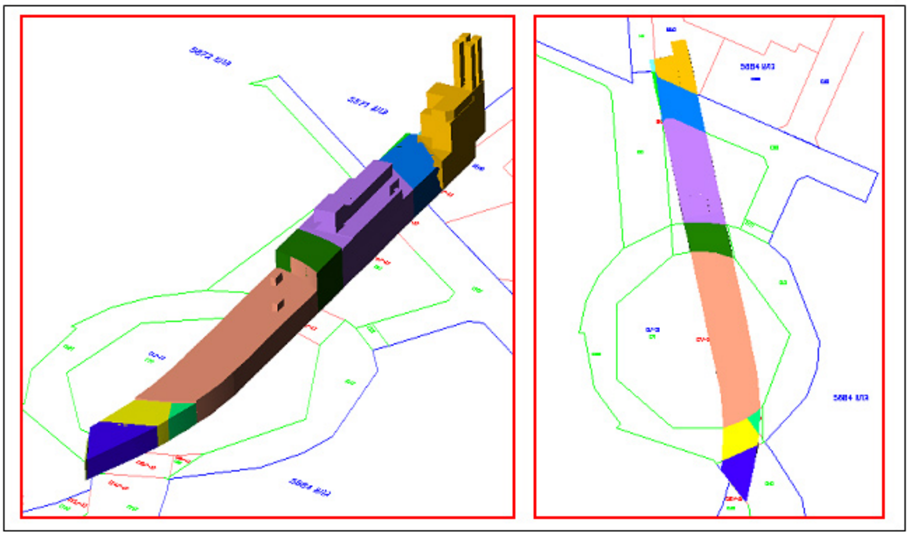

Figure 4: 3D and 2D Presentation of the spatial parcel and the spatial sub-parcels on the background on the existing land parcels – The railway station in the town center of Modi'in
A 3D model and 3D presentation of the roads and the railway
(By courtesy of Mr. Ronen Grinstein).

Integrated Data Model: The information database is to include only one surface cadastre layer (3D), with geospatial objects defined as objects linked to the surface layer. The surface information will be organized in layers and the multilayer information will be organized at the object level. Defined for each surface parcel will be indicators that will point to the multilayer objects related (or connected) to the surface parcel.
While the conventional information database management systems have proven to be beneficial and effective in many areas, the requirement in the areas dealt with by multilayer systems is for a more flexible approach with better and broader capabilities than those in the relational model. We consider the integrated data model to be the preferred model among the four alternatives, since it permits maintaining the surface cadastre layer, as well as being appropriate for the multilayer reality in which most of the activity is on the surface. Another and important advantage is the link between the surface information and the multilayer information.

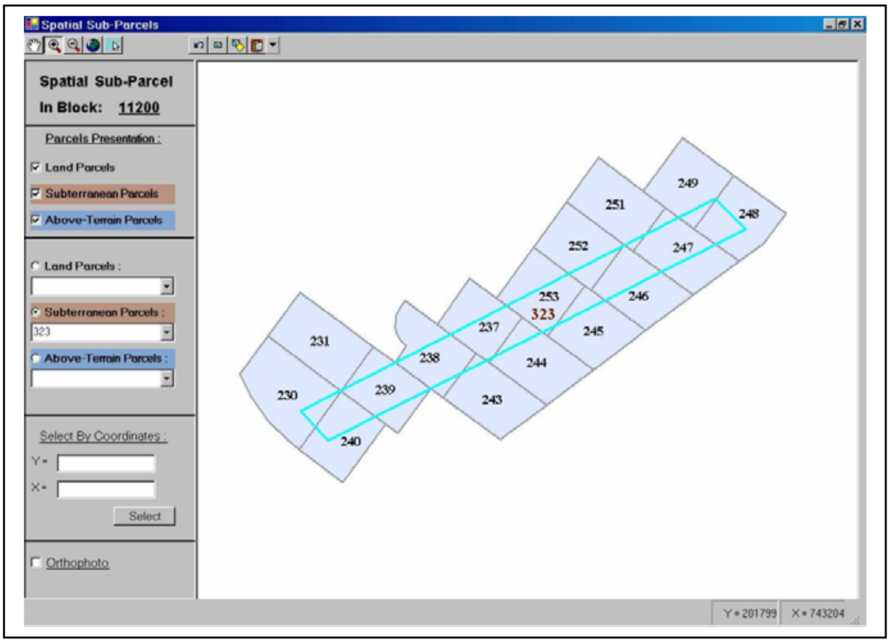

Figure 5: The original surface parcels regarding to the spatial parcel.

7. COMPUTERISED PROTOTYPE FOR 3D CADASTRE

Most existing GIS systems are substantially two-dimensional. Some of the systems contain a number of 3D functions for displaying a digital model of the terrain (mainly as a 2.5D), with the height maintained as a "property" of the object (Berry, Buckley and Ulbricht, 1998) without topological or 3D analysis abilities (Stoter 2000). CAD software has better 3D tools than GIS systems, but suffers from several disadvantages, primarily its limited information management tools and practically no good tools for analyzing the information (Christopher, 1998).

Technological developments in the computer field enable displaying geographic data in dynamic and interactive form, as a graphic animation. Animation is considered to be an effective tool for displaying a complex (2D or 3D) occurrence, changing in time (Smith and Paradis, 1989), (Van Driel, 1989). The animation production process includes five stages: obtaining and storing the x and y spatial components, adding the z component, creating single video frames, final editing and joining the frames and transferring the frame series to video (Okazaki, 1993). While in the past computer limitations did not permit creating real time animation, hardly any such restriction exists today (Ridland, 1998). There is supportive testimony for the idea that animation increases the ability to view hidden information within the information displayed. Use of animation may be effective in displaying the 3D cadastral reality. Some of the existing GIS software already contains some animation elements. Thus, for example, the ESRI/ArcInfo software package, one of the leading software programs in the GIS market, contains within its ArcTin feature (Ridland, 1998 and Stoter and Salzmann 2001) the possibility of creating an animated display of the information. Flyby Animation is obtained by a series of ArcPlot frames encoded for video. Each frame is a photograph of information. By controlling camera location, height and orientation and by adding fog and smog, it is possible to create a realistic simulation of flying above the surface.

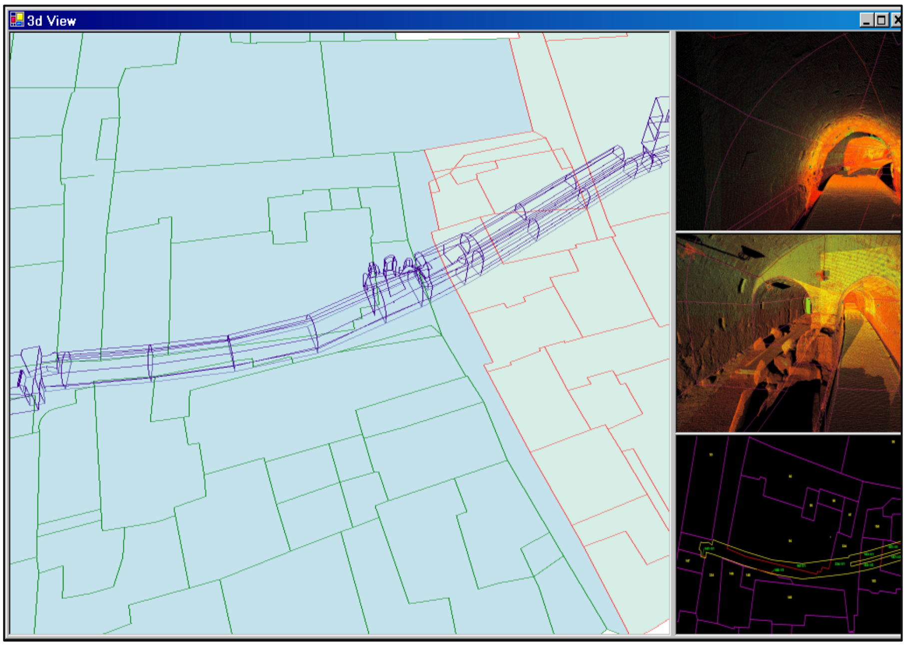

Figure 6: 3D visualization – A 3D display of the Templer Tunnel

One of the tasks of the 3D cadastre R&D project is the development of an active, computerized prototype of the Registration of Rights in space, in a GIS environment. The prototype of the GIS system is applied to the management of spatial cadastral database and will facilitate queries, visualization, production of reports and maps. The development of the prototype includes specification of the future GIS for the registration of spatial rights, as well as the development of a number of examples of application in order to demonstrate a routine use of the spatial cadastral information. These applications include amongst others: production of alphanumeric information pertaining to a surface parcel, a spatial sub-parcel, a spatial parcel and a registration block. Similarly, a two and three dimensional display of all spatial sub-parcels existing within the space related to a surface parcel, and a graphical display of the original surface parcels with their appropriate spatial parcels (as illustrated by figure 5) etc.

The ability to display 3D characteristics of properties, will facilitate a better definition of the judicial situation of the properties within the multilayer reality (as illustrated by figure 6). 3D representation corresponds better to reality than 2D representation (Van Driel, 1989). The three dimensional representation provides better tools for examining and analyzing the information that has thus far been represented by 2D tools only (Smith and Paradis, 1989).

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BIOGRAPHICAL NOTES

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