RESEARCH TOWARD A MULTILAYER 3D CADASTRE: INTERIM RESULTS

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ABSTRACT

This paper presents results of research dealing with geodetic and cadastral aspects of utilizing space above and below the surface. The research is being conducted at the Geodetic Engineering Division of the Technion - Israel Institute of Technology, as part of the doctoral studies of the first author. The principal objectives of the research are to find a cadastral-geodetic solution for utilizing above and below surface space and for defining the characteristics of the future analytical, three-dimensional and multilayer cadastre that will replace the existing two-dimensional graphical surface cadastre in Israel. The research objectives are being realized by attaining the secondary research objectives: defining the future cadastral reality and developing a multilayer cadastral model; defining guidelines for transition from the surface cadastre to the multilayer cadastre; developing a model for registering property rights in all three spaces; developing models for managing multilayer cadastre information and creating the geodetic-cadastral background for a legal solution of utilizing all land space.

INTRODUCTION

Existing cadastral systems are two-dimensional (2D) and deal with property located on the surface only *(Ball, 1991)*. It should be noted that while there are at present many buildings and substantial infrastructures below the surface *(Cramody and Raymond, 1993)*, the current cadastral systems barely deal with these. In recent years, due to considerable interest in utilizing the subterranean space there has been growing awareness of the necessity of finding a cadastral solution for multilayer construction.

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. Preparations are also underway in Israel toward the 3D and multilayer cadastre, both at the Survey of Israel (SOI) and at the Technion (the doctoral research which is the subject of this article). The various issues that are being examined within the research framework are detailed below.

MULTILAYER INFORMATION MANAGEMENT MODELS

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:

Layer Data Model: 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. The disadvantage of this alternative lies in its incompatibility with the continuous plane topology characteristic of existing GIS systems and the impossibility of performing multilayer analyses using the tools available in the current GIS systems.

Multilayer Data Model: 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. This alternative suffers from not being able to provide an answer to multilayer overlap, and it is moreover possible that in many areas the multilayer levels may be empty.

Object Oriented Database: 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. Since most of the currently existing information systems organize the information on the level of layers, rather than objects, the implementation of this model will make it difficult to transit from the surface cadastre to the multilayer cadastre. Furthermore, the link between objects in the various spaces is applicative, rather than built-in.

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 *(Aronoff, 1989)*. Most of the commercial GIS systems are based on a relational/tabular database model restricted in managing complex spatial information and executing complex spatial actions *(Heo, 1997)*, *(Laurini and Tompson, 1992a)*, *(Laurini and Tompson, 1992b)*. Information on any object is distributed among several tables, and thus the performance of applications is clumsy and slow. On the other hand, the object oriented database model is to accumulate all information related to a specific object and permit rapid retrieval of all existing information on that object *(Frank, 1998)*. The information will be organized at the level of objects, so that all information on any object whatsoever will be saved within the same framework *(Heo, 1997)*.

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.

ALTERNATIVES FOR REGISTERING MULTILEVEL AND MULTILAYER CONSTRUCTION BY EMPLOYING EXISTING TOOLS

This research was not intended to deal with the judicial aspect of the multilayer cadastre. However, since a dependency exists between the geodetic and cadastral solution and the judicial solution, we relate within the framework of formulating alternatives for solving the research issues, to the possible solutions within the current judicial framework, where under the Israel Land Law (of 1969), the property right in a land parcel extends heavenward from the center of the earth. Three alternatives for registering multilayer construction according to the existing registration method, are as follows:

Registration of Condominiums: Since most condominiums consist of several apartments build on top of each other, it is possible in any case to relate to condominium as a vertical parcelation, change in ownership in the parcel's space and multiplicity of owners and properties on the same parcel. The Registration of Condominiums Law governs the status of the rights of the several property owners at the same land site, and provides a judicial solution of separate ownership on levels *(stoter, 2000)*. An apartment in a condominium is a separate issue regarding ownership, rights and transactions. Application of this solution to the complex future multilayer reality is not optimal, since the method of registering condominiums refers only to the specific case of "orderly" vertical construction in apartment buildings.

Reducing the Three Dimensional "Reality" to Two Dimensions: In the case of a below surface or above surface object, according to existing registration possibilities, the object cannot be defined as a cadastral object (parcel) on the cadastral map and cannot serve as the basis for registration. Hence, parcels defined on the surface will serve as the opening for registering the spatial object – with the spatial object being divided into a number of parts corresponding to the surface parcels in whose space the object is located, and registered in each parcel will be the rights of the relative share of the spatial object located within its space.

"Benefit Commitment": Israeli Land Law permits conferring rights to a third party by registering the rights as a "benefit commitment". "Benefit commitment" can be registered in favor of the real estate, the public, specific person or a certain class of people. "Benefit commitment" can determine: right to a specific use of the real estate to the person in favor of whom the "benefit commitment" was granted; the owner of real estate in which there is "benefit commitment" must permit its utilization (in practice, "benefit commitment" constitutes restriction on the parcel owner's

proprietary rights). It is possible to consider expanding the "benefit commitment" so that it would permit imparting rights to a third party, also in respect to structures below and above the surface. A sketch that describes the multilayer reality is to be attached to the registration of the surface parcel.

3D Cadastral mapping

In the current land registration method in Israel, the registration map (cadastral block map) constitutes an integral part of the registration and serves to describe the property. The boundaries of the adjacent parcels, defined on the surface, require a 2D graphic representation of their borders, including the lengths of the boundary lines ("fronts") of each parcel. The cadastral maps are large-scale, intended to ensure the rights of the individual and the State to the property *(Fradkin and Doytsher, 1997)*. The present block map lacks any altimetric information, the contour lines are not drawn and the altitude of control points and objects is not noted. The block map contains partial planimetric information that assists in locating and reconstructing the parcel boundary and identifying the changes that have taken place in the area of the parcel and its vicinity. There is no detailed information on existing objects and structures in the parcel area, and almost no information regarding the existing infrastructure in the below surface and above surface space of the block.

The cadastral maps in Israel are currently kept in the district SOI offices in the original and distributed as needed in hard copy form on paper sheets. Within the framework of establishing the national cadastral information database, a digital format, corresponding to the parcel map, has been defined for the preparation of a program for registration purposes. From the judicial standpoint, it is still the paper map (hard copy) and not the digital map (soft copy) that constitutes the valid and statutorical document *(Fradkin and Doytsher, 1998)*.

Required within the framework of establishing the 3D cadastre is ability to describe in three-dimensions the location of the horizontal and vertical boundary between the units within the space. The ability to display 3D characteristics of properties, will facilitate a better definition of the judicial situation of the properties within the multilayer reality. 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)*. In any case, the techniques for 3D display are restricted to the 2D environment of the screen or the drafting paper, so that in practice we have to settle for a virtual 3D display which is a perspective of reality *(Hoinkes and Lange, 1995)*.

Display of the 3D information and the nature of the documents in the future cadastre are interdependent. The nature of the documents will affect the solution, while on the other hand, the solution will affect the nature of the documents. Two principal possibilities were examined:

a. A digital graphic document displayed as a hard copy on a computer monitor.
b. A 2D paper map.

If (and when) the digital document (soft copy) is granted legal validity, digital graphic documents saved on magnetic media will replace the paper maps in everyday work. The 3D cadastral map will be displayed by means of 3D graphic software. To facilitate the display of multilayer information on a digital map, it is necessary to examine the use of "transparency" – display of the multilayer reality against the background of the surface reality, by displaying the surface cadastre layer with high degree of brightness as the background for the multilayer levels. In addition, the use of "variable re-solution" - focusing on a surface object will lead to display of higher resolution information. Use of standard cartographic tools will make it easier to display the information: symbolization to distinguish between various spatial objects, multiplicity of windows – displaying information on multilayer activity in different windows/screens, perspective 3D display from several directions, as well as using multimedia - simulated reality, a kind of "spatial flight" within the boundaries of the cadastral map, etc.

It is estimated that establishing a complete digital 3D model will be costly, and it is thus possible that spatial properties that are not defined on the surface will be represented by projecting them on a plane and displaying these on a computer monitor and a paper map as a 2D map. Two possibilities exist: the block map will be a single map that displays objects from all three spaces; or alternatively, the block map will consist of a series of 2D maps – by subjects or the various spaces (a series of maps displaying the various spaces and a series of drawings displaying the parcel space from different angles).

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. 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)* 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.

BOUNDARY OF THE SPATIAL PARCEL AND SECONDARY SUBDIVISION OF SURFACE SPACES

Conceptual definition of the spatial parcel boundary

The fundamental principle of the practical application of 3D land management, is that the continuous ownership boundaries in the space are defined by spatial geometric bounding envelopes. The standards for determining the bounding bodies will be defined in accordance with geometric and juridical criteria, taking into consideration technological and economic applicability, considering real costs and a reasonable timetable. The conception of parcel in the current planar approach will become a spatial definition. The spatial parcel will be defined as an envelope bounding the ownership space, usually a virtual 3D object limited by volume. A number of possibilities exist for defining the boundary of a parcel, such as a series of faces, series of surfaces, a line forming a turning axis and turning radius and a joining of several simple bodies. In principle, there will be no limitations on the geometric form of the parcel in the future cadastre. The models for defining and representing 3D spatial objects may be classified into two principal forms:

Volume model: The spatial object will be defined as a combination of simple volume shapes, such as cube, prism and cylinder. This definition will lead to geometric uniformity and simplicity of the multilayer parcels and make it easier create a 3D display of these objects.

Boundary surfaces model: The spatial object is described by the surfaces by which it is bounded *(Cambray, 1993)*. The volume object is displayed as faces that have been connected, with each face defined by its boundaries, namely, the vertex and the bounding lines of the face. The foundation stones of this model are faces, edges and vertices, with each entity represented by a boundary representation tree.

It should be noted that these two models are based on surfaces and need to include information on the internal topology of the objects, in order to define a closed volume.

Subdivision of the land space

In the surface cadastre, the surface of the country is divided into continuous blocks and parcels, so that every two neighboring parcels share a joint boundary line and there is no overlapping between parcels. In the 3D cadastre, there will usually be no continuity of parcels (volume objects), due to the non-continuity existing in the multilayer utilization, concentrated mainly in the subterranean space of large city centers. Moreover, there might be a vertical overlap between the parcels and a spatial parcel may extend within a broad range of heights.

Due to differences between the existing cadastral reality and the future cadastral reality, it appears that it will not be possible to apply the current parcelation in the space above and under the surface. Within the framework of this research, two spatial parcelation alternatives were considered parcelation:

a. The total space of the State will be divided into three spaces (above the surface, on the surface and under the surface), with each space split into 3D parcels, without these being attributed to blocks. It should be kept in mind that the division into blocks in the present cadastre was created primarily to facilitate managing the information. In the future cadastre, in which the registration system will be computer-supported and all cadastral information will be managed and organized in a database, there will be no need for the division into blocks and the cadastre will be managed at the level of parcels/properties/objects.

b. The total space of the State will be divided into three spaces, with the parcelation of the surface continuing to be identical to the existing surface parcelation. The surface parcelation will preserve the division into blocks, but there will be no division into blocks in the other two spaces (similar to the above alternative). This alternative permits preserving the existing situation in the surface cadastre, thus permitting an easier transition from the present cadastre to the multilayer cadastre in the future.

Several possibilities exist regarding the manner of identifying the spatial parcels according to the data model that will be implemented, according to:

- Parcels defined in the new spaces, attributed to surface blocks and numbered in accordance with the existing numbering in the surface block.
- Total separation instituted between the numbering of the surface parcels and the spatial parcels.
- Spatial code attached to the block, not to the parcel, facilitating duplication of the surface subdivision and its application to the new spaces.

The multilayer land settlement

Utilization of all land spaces with the aim of facilitating registration of property rights in the space above and below the surface, requires bounding the space of the surface parcels and instituting a land settlement of the new spaces. At the first stage, measurement is to be undertaken of the existing properties located below the ground, bounding them by spatial parcels and separating them from the surface parcels, even if these parcels have not been settled as yet. For surface parcels, a process of reducing the parcel space will commence by defining the height and depth of ownership. Much of the subterranean part will be separated from the surface parcel by creating a subterranean parcel whose space extends to the center of the earth. Objects below and above the surface, that pass through an existing surface parcel, will be measured, mapped and registered in the parcel registration (similar to a "benefit commitment" registration). In cases of new construction projects that are not surface and are suitable for registration as a property that is separate from the surface parcel, a spatial parcelation below or above the ground will be instituted in the course of implementing the project. At the second stage, if necessary, the below surface parcels will be split and joined in a manner enabling the definition of a subterranean parcel bounding an existing subterranean property. It is noteworthy that while in the surface cadastre the standard order of activities is planning, parcelation and construction, the order in the future cadastre will be first planning, then construction, and finally parcelation.

As to implementing the settlement of the space above and below the surface, two alternatives were examined.

Local Rather than General Settlement: The process of defining a boundary below the surface and bounding a space of all surface parcels is a process that will require considerable resources and may give rise to disputes and problems. Therefore, it would be desirable that these actions of reducing the space of a parcel and defining a boundary below the surface be carried out only in those places where they are necessary, such as holders of rights that require this for establishing a new subterranean project. This method is fast, simple, and relatively inexpensive. It does not require determining a boundary except when the adjoining rights holders so desire. The disadvantage of this method is that it does not have the advantages of a concurrent arrangement of all boundaries in a particular area and it does not permit central and professional treatment of all functional and judicial aspects of a specific neighborhood. Its principal disadvantage stems from its being unable to ensure that the determination of the boundary is permanent, final and unappealable.

Theoretical 3D Spaces: An inexpensive and even simpler possibility of registering the 3D division of space below and above the surface is its subdivision into theoretical 3D spaces. This method permits division into independent property units even before utilization of the space. After completing utilization of the space, a more detailed division will be made of the built area. It should be noted that the spaces method will simplify the work of measuring and mapping, since it is easier to measure the boundaries and volume of a rectangular (for example) space, than measuring and marking the particulars of what is built and exists therein.

THIRD DIMENSION – THE DIMENSION OF HEIGHT

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 z 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:

1. Two dimensions, without any height information (corresponding to the current reality only).
2. Using "below the surface" and "above the surface" tags or "above surface", "below surface" and "surface", without any specific measurements.
3. Only a 2.5 dimensions.
4. Two dimensions including generalized height information - the boundaries of properties will be managed in two dimensions (x, y) with a height datum or several height datums maintained for each property.
5. A complete 3D representation.

The 2.5D is an intermediate situation between 2D and 3D *(Cambray, 1993)*. 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 *(Al-Taha and Barrera, 1990)*. For most spatial objects, which have several points with identical coordinates but with different heights, this option is inapplicable.

As stated, according to the Israeli Land Law, similar to judicial systems of many countries, proprietary right in the property is unrestricted and it extends from the center of the earth into the sky. The possibility of utilizing all land space and multilayer registration of propriety rights requires re-examination of the current definition of ownership boundaries in the property. It is necessary to consider the possibility of restricting the parcel volume and to carry out a vertical subdivision of the parcel's volume.

As to restricting the volume of the parcel, two possibilities exist: first - restricting the "right of use" volume and the "right of ownership" volume, so that the "upper" subterranean land would belong to the landowners, while the "lower" subterranean land would belong to the State.

The second possibility - reducing the "right of use" volume, but without reducing the "right of ownership" volume, so that use of the subterranean space of the parcel would be subject to consent of the owner of the surface parcel and to payment. Moreover, legislative amendments should be made to enable making transactions in the land spaces separately from the land, with or without the owner's agreement.

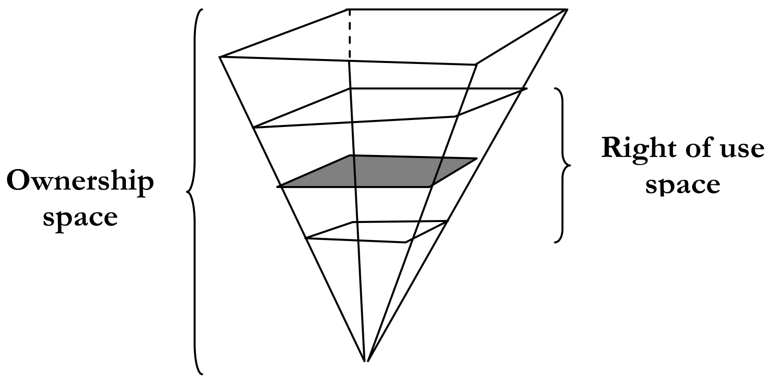

Figure 1: Right of use space and the right of ownership space.

In accordance with the judicial solution to be formulated, it appears that the future cadastre will incorporate several height data: "surface level height", "ownership height", "ownership depth", "right of use height" and "right of use depth". The surface height will be defined by coordinate *z* that will be maintained for each and every point, or a representative height that will be maintained for each and every parcel. The height and depth of ownership will be defined as additional properties of the parcel, with the possibility that these measurements will be uniform or variable, or variable in the parcel area or/and the block area.

Establishing 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)*. Since there is discontinuity in utilizing the above surface space and the below surface space, two alternatives are being considered: the first possibility is employing a "hybrid system", that involves establishing a 3D land cadastral database with national coverage, and establishing external databases that will refer to the existing properties that are not located on the surface. The second possibility is to employ an "integrated" system, consisting of storing all multilayer cadastral information in one single database.

Obtaining digital mapping data for establishing the 3D analytical cadastre, constitutes the bottleneck in establishing a cadastral information system *(Hoinkes and Lange, 1995)*. A radical solution exists, based entirely on a 3D remeasuring of all land boundaries with advanced instrumentation and analytical calculations. This possibility involves very high costs, for remeasuring and reconstructing the boundaries. An alternative solution is the possibility of using the original measurements in the field books for calculating the location, combined with a new measurement of height. Alternatively, it is possible to digitize the graphic data from the cadastral maps, once again in combination with new measurement of height – this being the least expensive and fastest for obtaining digital information, but also the least accurate, compared with the other possibilities *(Doytsher and Shmutter, 1991)*, *(Fradkin and Doytsher, 1998)*.

Another alternative, relating to a solution in which the volume of the parcel in the multilayer cadastre refers only to the land rights, without need of measuring the land parcel as a 3D object. In practice, the definition of spatial surface parcel will be effected according to existing digital surface data and the height and depth of ownership defined for each parcel.

Completion of the height dimension will be carried out by using one of the existing measuring methods (leveling, GPS and/or photogrammetry), with the possibility of integrating calculations based on a national digital terrain model (DTM).

Criteria for examining alternatives

This research encounters difficulty in analyzing most of the alternatives for solving the research problems. This difficulty stems from the inability to examine the alternatives by comparing numerical results or comparing the degree of accuracy. For the purpose of examining the various alternatives, eight criteria have been formulated:

1. ***Low Cost*** — The resources required to implement the alternative, implementation cost.
2. ***Feasibility*** — Existence of technological capabilities for implementing the alternative.
3. ***Flexibility*** — Adaptability to local conditions.
4. ***Lifetime*** — A long-range solution so that at the end of the process the implementation of the solution will still be relevant.
5. ***Continuity*** — Preserving (in part) the existing situation.
6. ***Advanced*** — Employing new and advanced technologies.
7. ***Quality*** — Providing a solution for all possible situations.
8. ***Professional criteria*** — Accuracy, cartographic quality, legal validity, etc.

In the course of the research, separate objective functions will be defined for each group of alternatives based on these eight criteria.

SUMMARY

The existing cadastre systems benefit from high reliability and a number of advantages, the outstanding of these being: State responsibility for proprietary rights; legal protection of the system; complete, methodical and up-to-date information coverage and good mapping, serving additional uses besides the cadastral. Notwithstanding these advantages, the current cadastral systems suffer from a number of disadvantages. The existing cadastre is graphic, two-dimensional and deals only with properties on the surface of the land. The existing cadastral systems, due to being surface and two-dimensional, are unsuitable for the multilayer geometric 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.

A number of actions have been initiated in Israel in preparation for the 3D cadastre, including the research that is the subject of this paper. Thus far, within the framework of this research work, an analysis of the alternatives for solving a series of problems in respect to the development and implementation of the 3D and multilayer cadastre was carried out. Examined also was the possibility of implementing the existing land parcelation in Israel in the new spaces, as were a number of additional models developed for implementing multilayer parcelation. Considered was a possibility to establish a 3D cadastral land database relying on the existing database, without need of new measurements, and the stages of establishing the cadastral multilayer database were defined. Moreover, models were developed for managing the multilayer cadastral information existing within the GIS system and in the object-based system, and capabilities and models for displaying the information in the future cadastre were examined.

This paper presents the intermediate results of the research. The research and its results may assist the authorities responsible for the cadastre and land registration to understand and characterize the future cadastral reality in order to define proper and accurate registration of land rights in the space below and above the surface.

REFERENCES

Al-Taha K. and R. Barrera (1990): Temporal Data and GIS: An Overview, Proceeding of the GIS/LIS'90, Annual Convention, Anaheim, USA, pp. 245-254.
Aronoff S. (1989): Geographic Information System - A Management Perspective, WDL Publications, Ottawa, Canada.
Ball W.E., (1991): Design Criteria for Three Dimensional Coordinate Computational Software for Future Land Information System, Proceedings of ACSM/ASPRS'91, Vol. 1 (Surveying), Annual Convention, Baltimore USA, pp. 13-23.
Berry J.K., D.J. Buckley and C. Ulbricht (1998): Visualize Realistic Landscapes, GIS World, Vol. 11(8), pp. 42-47.
Cambray B. (1993): Three Dimensional (3D) Modeling in a Geographical Database, AutoCarto 11, Proceedings of 11th International Symposium on Computer Assisted Cartography, Minnesota USA, pp. 338-347.
Campbell G. and R. Hastie (1998): Management of First Nations Lands Using GIS technology, Internet Site of Center for Surveying Energy, Mines and Resources.
Cramody J. and S. Raymond (1993): Underground Building Design, Published by Van Nostrand Reinhold Company, New-York.
Christopher J. (1998): Geographical Information System and Computer Cartography, Published by Longman, England.
Doytsher Y. and B. Shmutter (1991): Incorporating Known External Data in Information Digitized from Cadastral Maps, Proceedings of ACSM/ ASPRS'91 Annual Convention, Baltimore, USA, pp. 61-68.
Fradkin K. and Y. Doytsher (1997): Establishing Accurate Urban Digital Cadastre in Israel, CD Proceedings of GIS/LIS'97 Annual Convention.
Fradkin K. and Y. Doytsher (1998): Establishing a Digital Cadastre in Israel, CD Proceedings of FIG'98 Annual Congress, Brighton, England.
Frank A.U. (1998): An Object Oriented, Formal Approach to the Design of Cadastral Systems, Advances in GIS, pp. 245-261.
Gisiger A. (1998): AutoCad Map 3.0, GIS World, Vol. 11(10), pp. 72-73.
Guillet V. (1998): ArcView 3-D Analyst 1, GIS World, Vol. 11(10), pp. 73-74.
Heo J. (1997): An Object-Oriented Data Modeling for GIS, Proceedings of the ACSM/ASPRS'97 Annual Convention, Vol. 2 (GIS/GPS), pp. 73-81.
Hoinkes R., and E. Lange (1995): 3D for Free – Toolkit Expands Visual Dimensions in GIS, GIS World (July 1995).
Jones A., C. Rowe and P. Kentish (1999): Cadastral Reform, M&M, Measure and Map, Journal of Surveying and Mapping in Australia, pp. 23-26.
Kaufman J. and D. Steudler (1998): Cadastre 2014, Vision for a Future Cadastral System. In: Proceedings of FIG Commission 7. pp. 1-48.
Laurini R. and D. Tompson (1992a): Design for Information Systems, Fundamentals of Spatial Information System, pp. 340-351.

Laurini R. and D. Tompson (1992b): Spatial Object Modeling, Fundamentals of Spatial Information System, pp. 444-476.
Okazaki D. (1993): Visualizing Geographic Data Through Animation, AutoCarto 11, Proceedings of 11th International Symposium on Computer Assisted Cartography, Minnesota, USA, pp. 238-245.
Pratt M. (1998): Using Arc View GIS to Build a Baseball Stadium, Arc User, The Magazine for ESRI Software Users (April/June), pp. 60-61.
Ridland M. (1998): Creating Flyby Animation with Arc Tin, Arc Users, The Magazine for ESRI Software Users (April/June), pp. 38-39.
Smith D. and A. Paradis (1989): Three Dimensional GIS for The Earth Sciences, Three Dimensional Applications in Geographic Information Systems, Taylor & Francis Publishing, London, pp. 149-154.
Stoter J. (2000): Needs, Possibilities and Constraints to Develop a 3D Cadastral Registration System, Proceedings of UDMS 2000 - 22nd Urban Data Management Symposium, UDMS/TU Delft, pp. III.43-III.58.
Tulloch D.L., B.J. Niemann and E.F. Epstein (1996a): Comparative Study of Multipurpose Land Information Systems Development in Arkansas, Ohio, and Wisconsin, Proceedings of the GIS/LIS'96 Annual Convention, pp. 128-141.
Tulloch D.L., B.J. Niemann and E.F. Epstein (1996b): A Model of Multipurpose Land Information System Development in Communities: Forces, Factors, Stages, Indicators and Benefits, Proceedings of the GIS/LIS'96 Annual Convention, pp. 325-345.
Van Driel J.N. (1989): Three Dimensional Display of Geologic Data, Three Dimensional Applications in Geographic Information Systems, Taylor & Francis Publishing, London, pp. 1-9.

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