Use of 3D Cadastral Data for Real Estate Mass Valuation in the Urban Areas

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Key words: mass real estate valuation, 3D cadastre, SDBMS

SUMMARY

An assessment of real estate value is a prediction of its value based on experience, and taking into consideration its spatial, physical, legal and economic factors. Location has great influence on value because the real estate is being significantly determined by its spatial properties. In the urban areas, correlation between the value of real estate and its location is very complex and it depends on many subjective and objective factors. Mass valuation is a procedure which, based on objective factors, using statistical methods assesses the value of a big number of real estate. Modern, computer-assisted, real estate valuation systems worldwide are based on the existing spatial data, a combination of land administration and topographic data, along with the market factors. Efficient functioning of a real estate cadastre, as the basic infrastructural system, facilitates significantly the planning and accomplishment of economic and other activities linked to real estate.

This paper examines the possibilities of mass real estate valuation, based on 3D Vector Terrain Model, created from the digital cadastral map (DCM) of the cadastral municipality of Centre, provided by the City of Zagreb Office for Cadastre and Geodetic Works and topographical data. As in a cadastre, the basic unit of a realised real estate valuation system is real property, which can generally be seen as land, buildings, and whatever is attached or affixed to the land. In the lack of true 3D cadastral data models and data, procedures for real estate valuation were based on a model which consists of 3D physical objects made from 2D cadastral data (land parcels and buildings) and topographical data (elevation). Data were modelled, stored and analysed using the combination of PL/SQL procedures and Oracle 11g SDBMS built-in spatial functions.

This paper concentrates on further development of visibility analysis calculation of real estate, which requires a more detailed 3D physical model. The idea behind modelling the influence of this factor on real estate valuation is the assumption that a real estate with a bigger visibility polygon, i.e. a better view, has a bigger market value than the same real estate with a smaller visibility polygon. On the part of the model, each part of 3D property unit were manually modelled into smaller parts according to a plan of separate parts – 3D condominiums, which are the smallest parts of 3D property units in the model. As a consequence the procedure of automatic valuation of spatial characteristics of each condominium was possible, instead of valuation of the whole building object. This factor was calculated as visibility polygon, two-dimensional geometric shape – cross section of the continuous visibility border in all directions from one point (centre of 3D condominium), considering only the cross section of horizontal vision and obstacles. Data derived from the system can be used for better understanding and explanation of real estate value spatial distribution, and as a basis for the expert system based on multi criteria decision making.

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1. INTRODUCTION

Along with individual valuation of real estate, modern systems for land management demand a type of mass valuation of a large number of real estate in a certain area, which is especially notable in urban areas. The data obtained by these systems in general comprise and are made for a large area, of local or state character, and are used for just taxation of ownership or possession of a real estate, for helping the real estate market or land management in general.

In Croatia, as in other former communist countries, large cooperative farms on state owned land had neither a market nor any other value assigned to them. There was no need for valuation, gathering land use data and, the worst, no need for maintaining the information in property registers up-to-date. Therefore, a big effort in renewal of registers and other valuation factors has to be made, because unharmonized registers are blocking the investments and development of the real estate market. Effective functioning of the real estate cadastre, as the basic infrastructural system, supported by the SDBMS (Spatial Database Management System) or GIS technologies, greatly makes the procedure of planning and realization of economic and other activities connected to real estate easy. And as a consequence leads to realistic and justified causes of spatial development.

An assessment of real estate value is a prediction of its value based on experience, and taking into consideration its spatial, physical, legal and economic factors. Location has great influence on value because the real estate is being significantly determined by its spatial properties. In the urban areas, correlation between the value of real estate and its location is very complex and it depends on many subjective and objective factors. Mass valuation is a procedure by which, based on objective factors, a large number of real estate is valued. In order to regulate the relations in an area along with modern technological findings, many prerequisites have to be enabled – integration of attributes connected to an area, which are traditionally divided among several administrative bodies.

This paper examines possibilities of mass real estate valuation, based on 3D Vector Terrain Model, created from the digital cadastral map (DCM) of the cadastral municipality of Centre, provided by the City of Zagreb Office for Cadastre and Geodetic Works and topographical data. As in a cadastre, the basic unit of a realised real estate valuation system is real property, which can generally be seen as land, buildings, and whatever is attached or affixed to the land. In the lack of true 3D cadastral data models and data, procedures for real estate valuation were based on a model which consists of 3D physical objects made from 2D cadastral data (land parcels and buildings) and topographical data (elevation). Data were modelled, stored and analysed using the combination of PL/SQL procedures and Oracle 11g SDBMS built-in spatial functions. This paper concentrates on further development of visibility analysis calculation of real estate, which requires a more detailed 3D physical model. The idea behind modelling the influence of this factor on real estate valuation is the assumption that a real estate with a bigger visibility polygon, i.e. a better view, has a bigger market value than the same real estate with a smaller visibility polygon (Koomen et al. 2005, Yu et al. 2007).

2. A GENERAL VIEW ON MASS REAL ESTATE VALUATION

Along with individual real estate valuation, modern systems for land management demand a certain type of mass valuation of a big number of real estate on a certain area, which is especially notable in urban areas. The data obtained by these systems in general comprise of and are made for a bigger area, and are used for just taxation of ownership or possession of a real estate, for helping the real estate market or in general for area management.

Mass valuation of land is used for land taxation or possession of real estate since the foundation of tax cadastres, which was their main purpose. In individual methods, the details, i.e. the specific properties of each real estate, stand out and are given characteristics for them. Unlike these, in mass real estate valuation, the similarities are important, that is, an amount of mutually comparable data for all real estates which are part of the valuation process. The value of a real estate, valued by individual method, greatly depends on the experience and subjective feel of the appraiser. With mass valuation, depending on the method used, it is usually impossible to find outstanding features of real estates that are not common to the broad spectre of real estates in a certain area. The development of computer technologies for a longer period of time has enabled Computer-Assisted Mass Appraisal (CAMA) systems.

2.1 Methods of mass real estate valuation

Mass real estate valuation, due to its complexity and broad selection of methods, is a multidisciplinary procedure. Precisely because of that, experts in various fields: economy, civil engineering, surveying, statistics and information science, deal with that.
Mass valuation keeps the price of valuation low and valuation is not influenced by the subjective impression of the appraiser. In order to reflect the real value of the property, a sufficient number of valuations factors has to be known. The most commonly used mass valuation methods (Garcia et al. 2008) are:

– Geographic Information System (GIS),
– Artificial Neural Network (ANN),
– Multiple Regression Analysis (MRA),
– and combinations of them.

Although the selection of the valuation method greatly depends on the state of the market and the state of area data, multiple regression analysis is the dominant and traditionally ingrained method. Multiple regression analysis has the purpose of determining the function of the influence of various attributes of a real estate on the total value and uses the regression variables, which can be divided into external, i.e. variables connected to the location of a real estate, and internal variables, i.e. physical characteristics of a real estate. Therefore it can be said that some of the external characteristics concern the broader position of a real estate within a municipality or some other local area unit, as well as the micro location – the quality of a position within a zone defined by an area plan. The physical characteristics would be technical characteristics of a real estate: the surface of the parcel, buildings on it, and their technical characteristics etc (Figure 1).

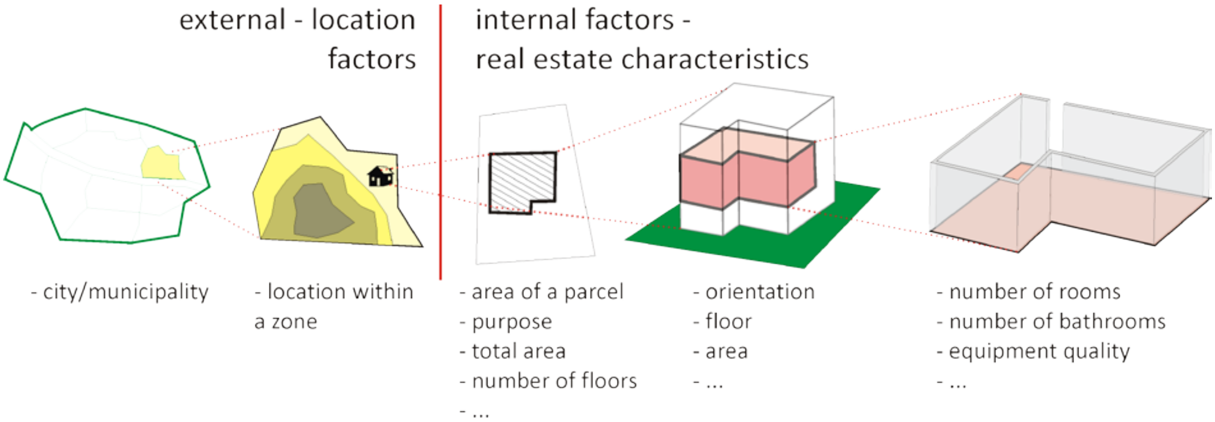

Figure 1. Division of real estate characteristics

3. CURRENT STATE OF THE LAND ADMINISTRATION SYSTEM AND MASS VALUATION IN CROATIA

3.1 Definitions and legal aspects of real estate registration

Although traditional cadastre registers 2D parcels, ownership and other real property rights are not limited to 2D parcel boundaries. The Law on State Surveying and Cadastre of Real Property from year 2007 defines cadastre of real property as register of land parcels, buildings and building parts, and other structures permanently on land or below the surface.

In the past 10 years, significant financial means have been invested in the improvement of the land administration systems. Several projects for improving land books and cadastres have been implemented. The main goals for all these projects have been coordination and connection of all cadastral data and data registered in land registers (Vučić 2010). It will only be possible to found a 3D cadastre if all the data in the above mentioned registers are harmonized.

Buildings and other structures are registered in the cadastre and in the land book with following attributes: area, building use, name, and address. Apart from registering the whole building, it is possible to register particular parts of buildings according to the report of partition of real property. By that plan, it is possible to divide a real estate – condominium of common and separate parts and register them in a land book. A long-term and complicated procedure has led to the current situation in which condominiums are registered only in small parts, and they usually refer to newly built buildings.

3.2 Real estate valuation

Mass real estate valuation for the need of taxation in Croatian cadastre has been done since the Franciscan cadastre (Roić et al. 1999). In that period, cadastral datasets have been made according to prescribed instructions and legends, which were limited primarily to signatures needed for the function of just taxation. Implementation of additional cadastral functions means that signs for real world objects should be more detailed. However, cadastral land valuation, i.e. cadastral classification with the purpose of determining cadastral income from agricultural production, always remains an important part of the operator.

The disappearance of a primary tax purpose of these data has led to irregular maintenance of data, and finally to the cessation of data collection for land classification, i.e. calculation of cadastral income. Maintaining the data on cadastral income was stopped on January 1st 2001 by the Law on State Measurement and Real Estate Cadastre. As a consequence the only way of valuation of agricultural land in official registers has been abolished.

4. IMPLEMENTATION OF TEST SYTEM

In the previous research at the Chair for Spatial Information Management, Faculty of Geodesy, University of Zagreb, various factors of real estate valuation were modelled and analysed, and particular functions which automatically calculate the influence of specific factors were created (Matijević et al. 2006, Roić et al. 2007, Tomić et al. 2010, Tomić 2010).

A digital terrain model (DTM) of the test area is created by combining and modelling a digital relief model (DRM) and a digital building model (DBM), and storing them into a spatial database. In this way spatial data are transformed to be applicable for a visibility analysis through combining spatial queries in the database. The spatial queries combine the classic logic SQL operators and widen the query by spatial functions. From the areas enclosed by line elements in the layer of border lines in the DCM, within which the number of cadastral parcel is written, 2D polygons are modelled, suitable to be entered into the spatial database.

Cadastral parcels are thus stored in the “CESTICA” table (Figure 2), with a SDO-GEOMETRY-type column for describing geometry of a 2D object polygon, together with data on the parcel number and area. Buildings are or a DBM is stored in the GRAD table, in the column entitled “geom” and with a SDO_GEOMETRY type, which stores 3D bodies that the buildings enclose.

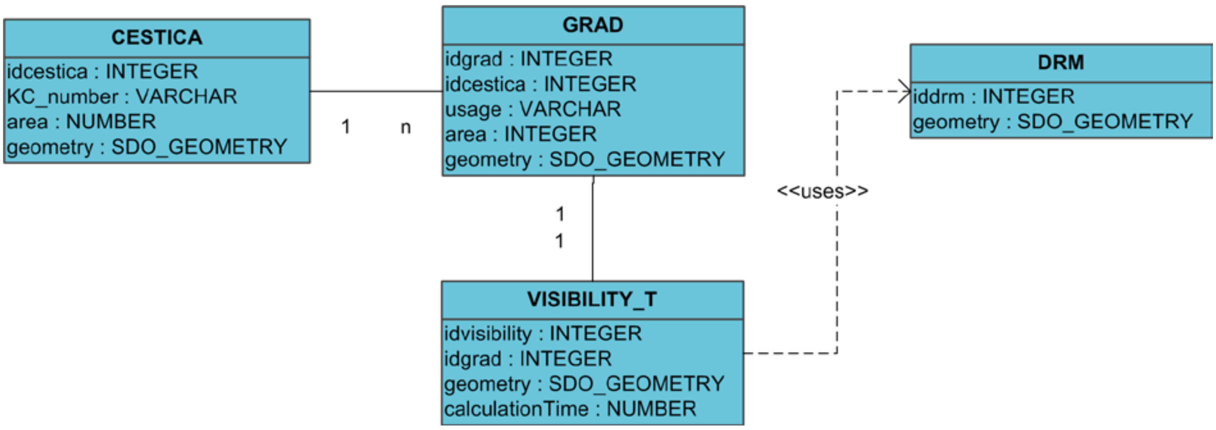

Figure 2. Class diagram of system data structure

The 3D bodies (DBM; Figure 3) are made on the basis of blueprint data on the DCM buildings. As height, the value of the closest point of the digital relief model is taken.

The data from the digital cadastral plan have been transformed in the previously described form by using FME (Feature Manipulation Engine) software. The software enables the production of automated procedures for remodelling and topological structuring of data. Records are in the 3D Oracle spatial data type. The own procedure which has been made, is based on two-dimensional data from the DCM as well as the Croatian Base Map (M 1:5000) and creates 3D geometrical bodies on which it is possible to apply Boolean operations.

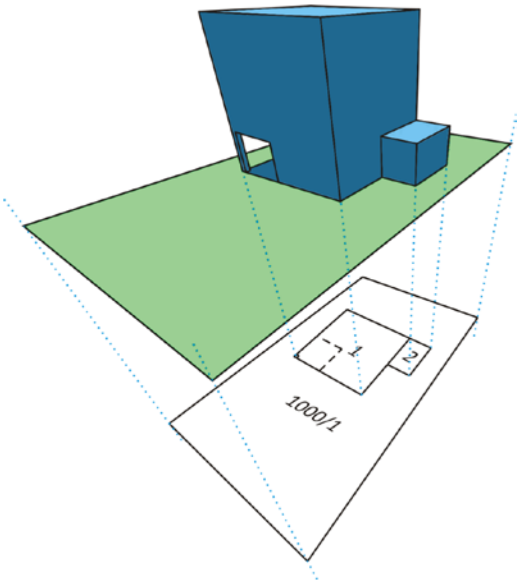

Figure 3. Modelling of buildings based on DCM

A digital relief model (DRM) for the test area has been made on the basis of triangulation points taken from the contour lines and altitudes of the Croatian basic map sheets. Split points are added at the intersections of buildings and terrain, to keep topological accuracy (Figure 4).

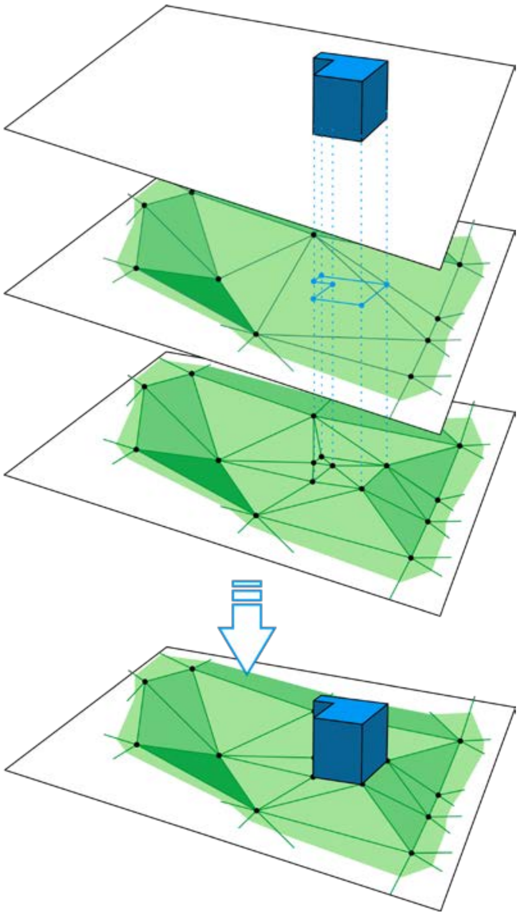

Figure 4. Creation and modelling of DTM

5. CALCULATION OF VISIBILITY POLYGON

The idea behind modelling the influence of this factor on real estate valuation is the assumption that a real estate with a bigger visibility polygon, i.e. a better view, has a bigger market value than the same real estate with a smaller visibility polygon (Lake et al. 1998, Yu et al. 2007, Koomen et al. 2005). In the earliest studies, the quality of view had to be examined by field inspection for each particular building. This approach is not satisfactory for the mass real estate valuation, and this assessment needs to be expressed in objective and measureable parameters, in this case in the geometry of visibility polygon and its area or volume (Figure 5).

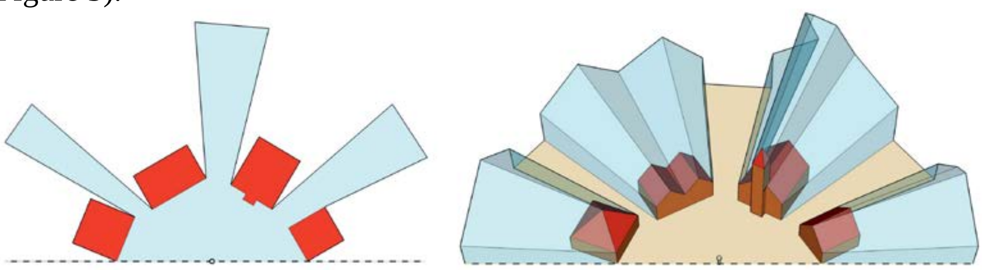

Figure 5. Examples of a 2D and a 3D visibility polygon (Bilsen 2008)

The procedure in this paper calculates a 2D visibility polygon (Figure 6) by taking an intersection between the horizontal vision in all directions and its first obstacle in a 3D space model. The obstacle can be a building or a terrain which cuts the vision. Modelling of influence of this factor is useful only as part of a wider calculation, based on a bigger number of objective valuation factors.

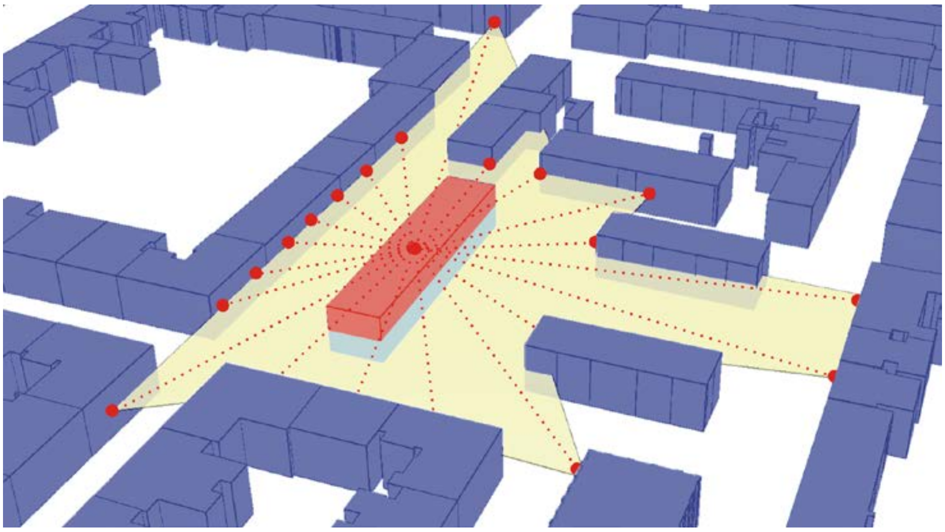

Figure 6. Example of a calculated visibility polygon

Although you could easily think, based on the previous picture, that the visibility polygon is determined only by intersection between horizontal vistas and buildings, this is the case only in densely built parts of the test system. In the scarcely built part of the model visibility polygons are determined also by the intersections of the vistas with the terrain (Figure 7).

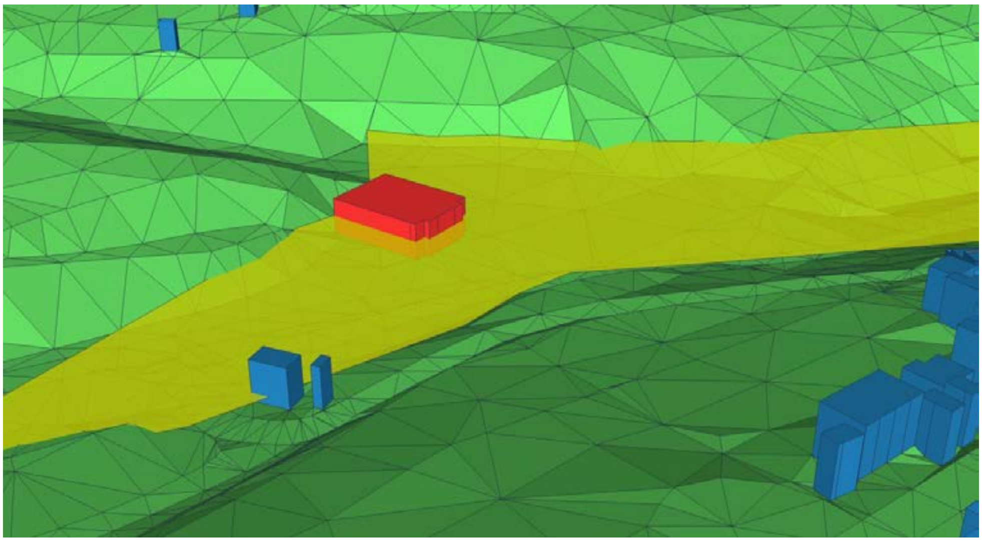

Figure 7. Visibility polygon (yellow area) bordered by terrain

By this approach, for every building the information on its visibility polygon is determined and assigned. In that way it is possible to correctly determine the visibility polygon for separate parts of a real estate. But it is necessary to have a real estate modelled in such a way that every individual part is determined as an individual 3D body.

Based on the created model and the described procedure the visibility polygon is calculated and assigned to each of the 13137 buildings of the test model (Figure 8).

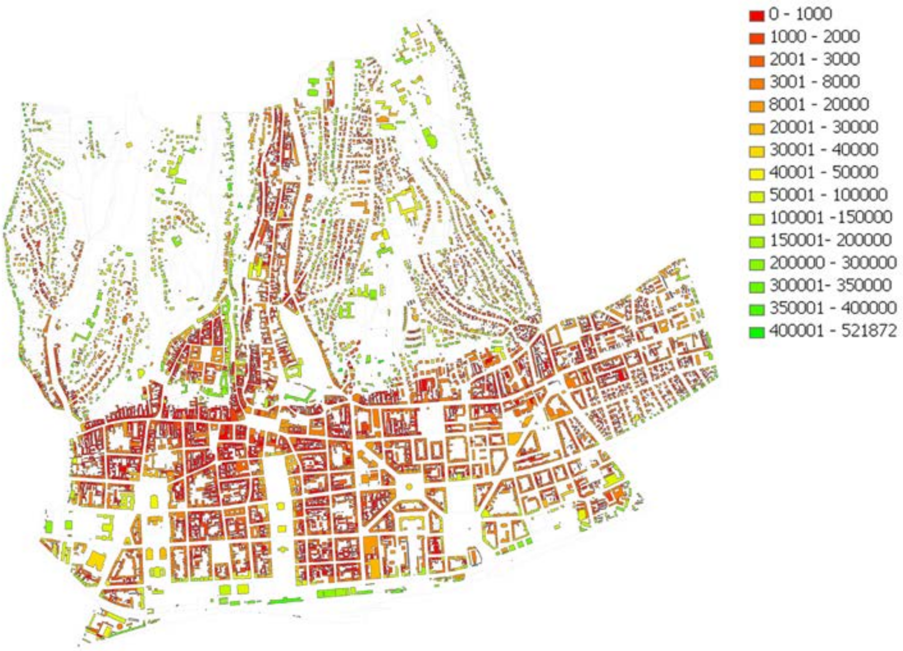

Figure 8. Thematic display of the visibility polygon area [m2] for the whole test area

5.1 More detailed calculation of visibility polygons according to the plan of particular parts of real property

For calculation of more accurate data by the suggested method, it is necessary to model buildings in more detail, i.e. to model parts of real estate separately according to a plan of separate parts of real property. This enables a more detailed approach to quantify the value of a visibility polygon calculated for each separate part of real estate, instead of only one for the whole building.

Figure 9 demonstrates a part of the graphic elaborated for the implementation of separate parts of real estate. It shows the layout of the ground floor of a building, with the impossibility of unambiguity of spatial and height determination of borders of actual rights. Based on the above mentioned elaboration within this work, a model of separate parts of a building has been made (Figure 10). For the model, the previously described procedure has been used to determine the visibility polygon. Obviously in that way it is possible to emphasise and quantitively express individual characteristics of separate parts of a real estate.

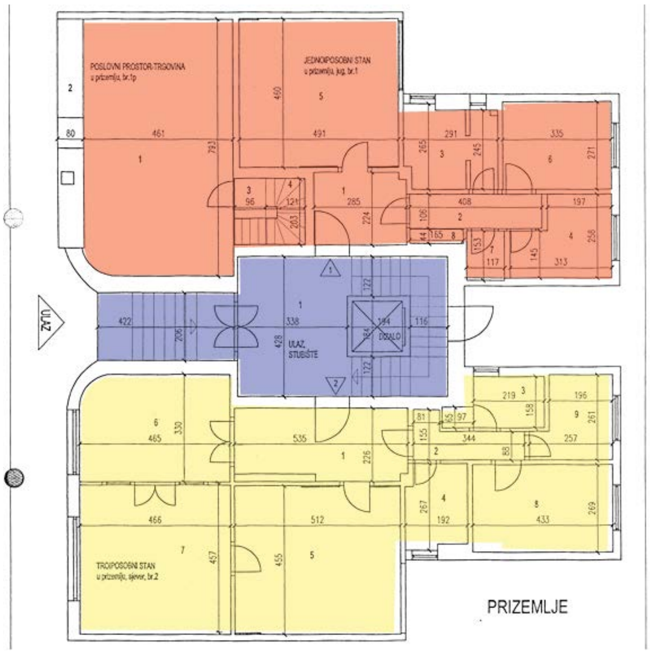

Figure 9. Part of the graphic elaborated for the implementation of separate parts of real estate

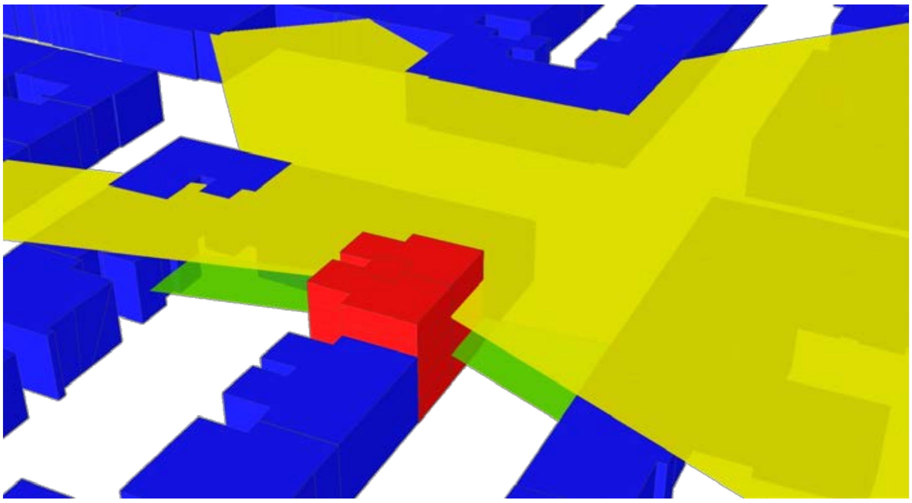

Figure 10. Visibility polygon for separate parts of a real estate

5.1.1 <u>Possible analysis of the position of separate parts of a real estate within a building</u>

Three dimensional modelling of particular parts of real estate according to the plan of separate parts enables the determination of quality of position of an individual separate part – for example a floor in a special part and its orientation in different directions.

Figure 11 shows the example of a procedure which is based on the visibility polygon and a combination of functions built in the spatial-relation database to determine the orientation. The procedure encompasses determination of the intersection of the border of a separate part of a real estate (in the figure the grey polygon) with the interior of the adjoining visibility polygon (yellow polygon), determination of a polygon based on the resulting intersection (red polygon), calculation of the centre of a special part of a real estate and the centre of the polygon of the intersection (in the figure marked with circles), and the final calculation of the angle which represents the orientation of this particular part of a real estate.

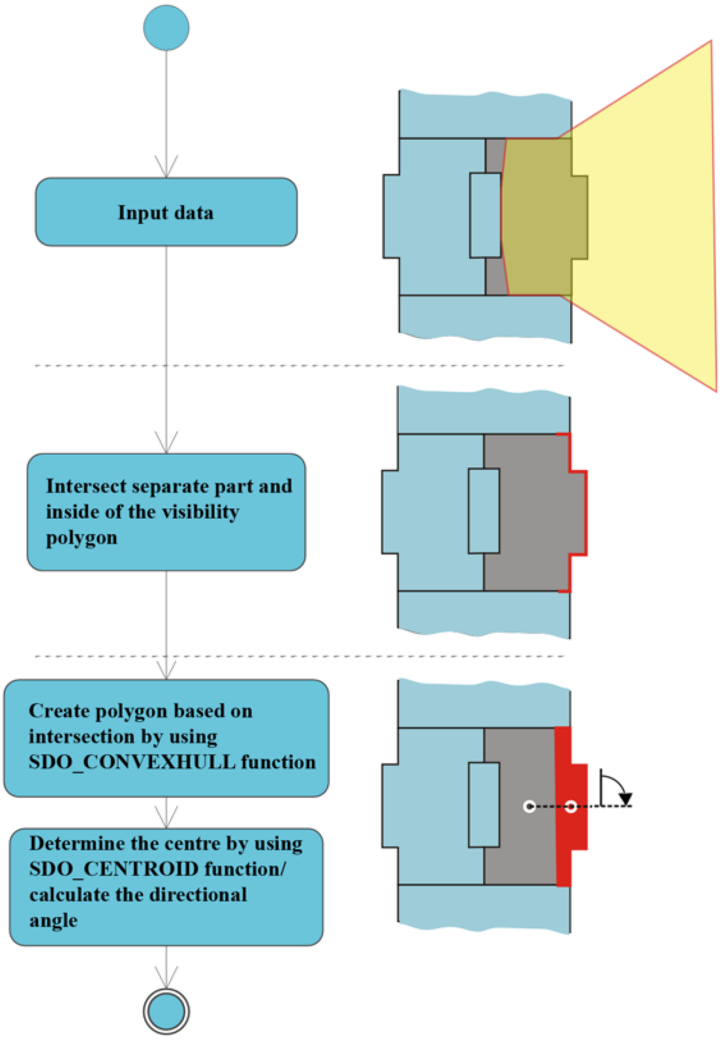

Figure 11. Diagram of the activity and display of the procedure of determination of orientation of separate parts of a real estate

Further determination of the orientation encompasses calculation of the centre of an intersection and the centre of the separate part, as well as the determination of the directional angle, which represents the final value of the separate unit orientation. This procedure has not been used in the further procedure of the calculation of the value of factors due to the limitation of the model made in the framework, i.e. modelling only one test building based on the elaboration of the separate parts of a real estate. However, the proposed method of determining visibility polygons can be applied in the case of condominiums created for the whole model area.

6. CONCLUSION

Real estate valuation factors can be divided into external ones, connected to a real estate location, and internal ones, which are physical characteristics of a real estate. Determining the visibility polygon for a separate part of a real estate is only one of the internal real estate valuation factors and their use can be seen only as a supplement to other important factors, such as: age of a building, number of bedrooms, quality of built, state of installations, etc.

It is possible by the use of automated procedures to apply the proposed methods to the visibility polygons for all real estate stored in the model. The visibility polygon determined in such a way is usable in the procedures of mass valuation, but only after quantitative determination of its influence on real estate value. For the above mentioned, it is necessary to have enough information on transactions, based on what one can examine related to possible correlation with real estate value in a certain area.

A model made in such a way is certainly uneconomical if it is applied only for the determination of the visibility polygon. Therefore the purpose of this work is to explore the possibility of mass real estate valuation based on the already established 3D cadastral system. With that in mind, it is possible to start the mass real estate valuation with minimal cost because all the necessary data for the determination of the appraised value would be obtained from the distributed databases of land administration.

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BIOGRAPHICAL NOTES

Hrvoje Tomić works as a university assistant at the Chair of Spatial Information at the Faculty of Geodesy in Zagreb. In 2010 he defended his Ph.D. thesis about "Geospatial Data Analysis in Purpose of Real Estate Valuation in Urban Areas" at the same University. His main research interests are GIS and DBMS technology in spatial data handling. Hrvoje Tomić has participated in several projects and has published several papers.

Miodrag Roić graduated in Geodesy from the University of Zagreb, Faculty of Geodesy. In 1994, he received a PhD from the Technical University Vienna for the thesis "Surveying of Natural 3D-Structures with Video-theodolites". Since 1996, he is a professor at the University of Zagreb, Faculty of Geodesy. He was Vice Dean of the Faculty, Head of the Chair of Spatial Information Management and the Institute of Engineering Geodesy, and he is appointed as Dean for 2011-2013. The topics that he specializes in are land administration systems, engineering geodesy, cadastres and geoinformatics. He was an editor-in-chief of "Geodetski list", an internationally recognized Croatian scientific geodetic journal. He is a corresponding member of the German Geodetic Commission (DGK) and many other national and international scientific and professional institutions.

Siniša Mastelić Ivić works as a Professor at Department of Applied Geodesy, University of Zagreb, Croatia. He participates actively in numerous projects at international and national level. In 1996 he defended his Ph.D. thesis at Vienna University of Technology. His main research interests are land management and real estate valuation. He has published more than 20 scientific papers.

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