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Interpretation of 3D city models for Sustainable Urban Development

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Abstract. Many urban or environmental models are determined with the objective to help practitioners and stakeholders in the processes of decision making. The models represented in 3D dimensional geometry are elements of a city and are called 3D models cities. In a wide range, these models are more and more being used for different cities and countries, for purposes beyond simple visualization. Possibility of using of this kind of models, in introducing semantics as geometric aspects, leads into enriching the semantics of 3D city models. Furthermore, in the perspective of sustainable development, cities should be studied in thorough and comprehensive way, taking into account inter relation of many different questions and problematic issues that are related to the future development of urban areas. This can be achieved through the identification and utilization of knowledge about the data and the models, too. The use of ontology is a powerful way to reach the semantic enrichment of 3D city models and also their interoperability with other urban models, so that they become an effective matrix of urban knowledge with a perspective of sustainability.
This action will enable:
Integrative platform based on semantics enrichment of 3D city models,
Use of ontological methodology that can be reused,
Evaluating the usability of integrative platform for planning and decision making.

Key words: 3D model, 3D object, DMR, DTM, TIN, Vectorization, Kosovaref01.

1 Introduction

This topic has the task to illustrate the creation of 3D models of terrain and 3D objects based on existing (collected geodetic data) or measurement of factual situation of terrain, for one part of the city Mitrovica. The purpose of this project was generating design of regulatory plan, as inevitable basis for the management of urban plan for the city Mitrovica.
Works for the purpose of recording and collecting of these data, carried out in period on between 2010 and 2011. Contractors of the project for doing the surveying and modeling works, were two private surveying company "GeoInfo" in Pristina and "Geo - Consulting", also based in Pristina.
The main company, that was responsible for making a design of regulatory urban plan, was the company "Linproject" based in Mitrovica. The investor of the project is the Municipal Assembly of Mitrovica.
Furthermore, this seminar will mainly deal with the problem which describing the works, that directly touch the collection of geodetic data and the creation of such 3D models for spatial planning. Other actions, such as urban solutions or regulatory plan solutions, will not be the focus in this area of activity.

2 Preparation of data prior to the process of surveying a terrain with its associated facilities

Beside the geodetic source data measurements, there also were used the existing urban maps of the scale 1:1000, which were produced on 1987. Initially the maps were scanned and georeferenced, according to the administrative guideline 2005/08 for scanning and dereferencing maps. The following process is transformation of these data, from the old system named Fryref30 (Gauss-Krüger) to the new state coordinate system named Kosovaref01. The above mentioned derived data records, are very important, and this data shall be used at further process for new measurements, which will be carried on the field. Transformation, of the old coordinate system Fryref30 to the new Kosovare01 system, is based on the principles of affine data transformation of the triangles elements (triangles network), well known method in the geodesy.

The principle of this transformation is as follows:

- Definition of triangles: required points (triangulation points - reference network points) of order I, II or III and existing trigonometric points measured in both systems.
- All points within the triangle are transformed with the same set of transformation. Coordinates of points are required in both geodetic reference systems.
- Points are primarily those of the network order I and II, and if is a need will be added some additional measured points.
- It is important to be used points which did not changed since of their definition from original adjustment.
- If it is possible to be used stable points, as basic point of transformation and to be used the suitable points for GPS (Global Position System) measurements.

The density of points under the transformation depends on the quality of data from Fryref30 system and the level of tolerance. Hereinafter the local transformation is used the Helmert transformation for the entire surface of the country. In this transformation will be included, the transformation of base points and the checkpoints. The guideline No. 2005/9 outlines the steps for working with vectorization data as part of using data model for Kosovo, while for quality control for the vectorized data, is used the guideline No. 2005/11, as well as proper application of Kosovo Cadastral Land Information System in (KCLIS).

2.1 Surveying of the detail of terrain

At first stage is planned the reconciliation of reference network points of III order, and then from these reference points, will be taken in action the process of the measuring of detail requested from the project. Instruction on reconciliation of the III reference network is outlined in guideline No. 2005/ 04.

- Measurements of reference network points of third (III) order are made in two ways:
- TPS (Total - positioning station)
- GPS (RTK - Real Time Kinematics)
- Measurements of detail on the ground and facilities on surface are carried out under the guideline No. 2005/ 06 on detailed measurements.
- Measurements were performed with the combined method of measuring by using: measurements of advanced GPS technology (GPS 1201and 530) and total station measurements (Flex line TS09 total station, TCR 1200 and 1103).

3 Methodology for surveying of facilities for creating of 3D facility objects

Geodetic measurements were carried out through the polar geodetic method, well known method in geodesy, from where are derived the coordinates (x, y, z) of each measured points of the DTM (Digital Terrain Model). All footprints of facilities on the ground are measured from the same principle of polar method of measurements.

Presentation of the third dimension of facilities is done interactively, by using the combined methods: measuring of heights of facilities from instruments (total stations) and by classic measuring of heights of facility. Because of the density of buildings and neighborhoods close, it was a very high cost from investor for doing of such a measuring facilities heights from the instruments, by other hand using the classical methods of measuring of the heights of facilities meet this criterion and has been sufficient accuracy to which it has seeking investor. Therefore, for this reason, the majority of measurements of

facilities heights are being made by this classical method. With this classical method, the principle of measuring of these heights is done in such a way, that first is measured the height of a floor and also the height of between the ground and that measured floor, after then calculated of thus cumulative partial floor height and by this principle is derived the height of the site of facility.
3.1 Surveying and prescription of note-marks of the heights of objects (facilities) in the operational terrain sketch map
a). For optimal flatten terrain: determination of heights of buildings is done as followed: operator during the site visits on the field; he measured the height of one site of object (facility), and then this data height recorded in his operational sketch. Operators (surveyor, technician) have made measurements of the heights of objects, during the field campaign measurements, or even later after processing the DTM data.

b). For none flatten terrains: is used an appropriate method, known as rapid measurement of heights of facilities. It has been measured the height of the site of object (facility), where the facility best feet with terrain. Through this principle operator or expert, has measured the heights of all these facilities, based on his position of view to the facility and according to the position of the terrain. By this method operator decide that to which side of facility should be measured the height of the facility. After reading of floor height of facility, the operators also marked these data heights in the operational terrain sketch.

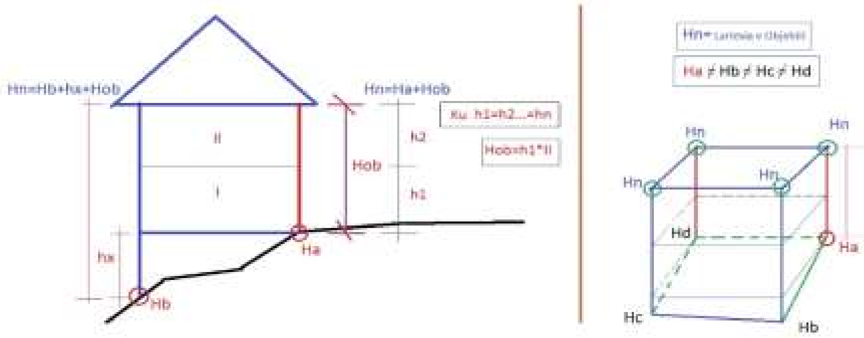

Fig. 1. Measuring the height of the object (facility), determination of the peak point of 3D object.

3.2 Processing of the recorded detail of the terrain and data processing of elevation of facilities

The collected data on measurements of factual situation of terrain and heights of all buildings ends up on the further processing in the office. The continuity of data processing has progressed in such way, that the majority of the measurements of data is actually in advance independently analyzed and processed. Later on follows the process of the independently connection of details, from the prepared sketches derived from the field measurements, where this will be further manually processed by the operators in the office. After the connection of details (2D situation plan) form the operators in the office, the other team that was responsible only for measuring the heights of facilities (they initially measured height of each facility), later on this team independently reprocessed collected height data and adopted these data for the prepared 2D situation plan. This process was conducted in the following way: firstly processed each measured partial height (from their own sketches prepared during the height measurements) then calculated the respective heights of each facility, as result of multiplication between partial heights and the number of facility floors. By calculating the cumulative amount of highest peak for each facility, will result on getting the final altitude peak of each respective facility. For the field work have been used pre processed sketches of 2D situational plans, along with the orthophoto. The entire work should be done in the way, that all forthcoming data processing and these data preparations have to be well prepared in advance and also well designed for data formats, for further automatic data processing in creation of real 3D model (3D modeling). It is required a well pre-planned connectivity elements of details. Such preparation or designed plan for this purpose, has to be used according to the rules based on: setting of each element of details and then after to be prepared and utilized for the following steps into the process of modeling of terrain, i.e. creating DTM and creating 3D facilities (modeling of objects).

Fig. 2. Excerpt of height data presentation, sketch of the 2D situational plan (URL7).

3.3 Processing of measured data for creating of DTM

In order to prepare and create DTM, initially is constructed the DMR from the measured terrain elevation data. Later to repair this DMR model in order to adopt to the reality of the terrain (the DTM), the DMR has to be prepared for further processing steps: the elimination an correction due to the wrong connectivity of triangles in the TIN network, the correction due to vegetation and steepness of certain characteristic terrain or facilities.

Facilities with all the characteristic elements, as well as those parts of the field which in one or another way have a specific form, or by themselves may contain different types of penetration such as various types of channels, streams, water, roads, rivers, bridges, garages, etc. All mentioned penetrations should be recognizable through site visit, due to the measurements on the field, or can be seen through the data analysis at the steps when 2D situation plan was created, or on process of creation of DMR. Today's software's applications that contain in themselves the module for creating of TIN models, their principles are based on a mathematical principle for creating triangulation model. In other words these modules are functioning due to the logic of connecting the nearest neighboring points of the circle domain and in this way is created a network of TIN triangles.

In other words such triangles are represented in themselves as triangle points, or exist as form of triangle block in the triangular network TIN. Other form of TIN creation is known as foursquare DIN network. In most cases we are facing with the characteristic shapes of the terrain, and because of their specific, with such distinctive objects (objects that penetrate) it is impossible to properly make adequate connection of triangle points without our manual intervention. Without our intervention on parts of triangles can not be created real its TIN network and consequently it would not really fit the facts on the ground, neither can be formed the shapes of early mentioned characteristic objects.

For all of the above facts, with a large degree of certainty we can say that, the creation of more accurate forms of bounds, and also making shapes of these kind of characteristic objects, is simply impossible creation of model without our manual intervention on the stage of automatic creation of model. That is, our intervention is based on 2D plans and specific reconnaissance field trips, and also by adding the newest measured points or reconstructed ones on the DMR model, with the purpose of achieving a precise DTM.

In some cases, even with our detailed intervention in these characteristic parts of the terrain or the characteristic shapes of objects, our efforts would be in vain before the automated process will create TIN. It is impossible to create these types of characteristic structures through automated tools for the creation of certain TIN. We encounter with these cases when it comes to specific objects such as bridges, tunnels, underpasses, etc. Therefore, it is of utmost importance planning in advance which objects we leave for creation through the automatic processing a TIN and which one to be treated or created outside

of the automatic process. This can be achieved through other processes or by other graphical tools for creating of models of these objects, and then inclusion of these models to our finalized model of DTM. Therefore, for some processes within the TIN processing and in the case of our additional interventions it is quite often needed to be added a new geometric elements. For those actions outside of the domain of processing of DTM creation and processing of these data we need in advance to design the structure with ready-made prepared steps. We need to be able to really think it through and make a decision on which way we will create characteristic shapes of the terrain or objects. For example, the issue of bridges, initially we only consider the ground under the bridge as DTM process. In order to facilitate processing of the 3D bridge model, this has to be done outside of DTM process and the data will be prepared for 3D creation of the bridge, through other graphical tools and such 3D finalized format will be added to the DTM.
In this case, the geometric shapes of such objects are independently processed as 3D objects, and these data shall never be treated in automatic process in creating TIN model.
Having in mind, all these so far mentioned actions among the various processing and a variety of methods for creating of these typical forms of terrain or buildings. properly prepared well handled processing of data, the stage of 2D situational plan (but always based on the facts and realities on the ground), we can always achieve the goal of creating a more accurate DTM, as well as the approximate precision of creating realistic 3D objects characteristic , along with their factual situation on the ground .

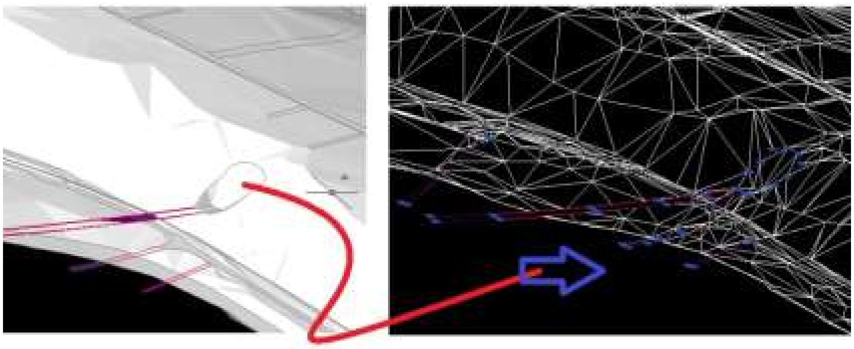

Fig. 3. Bridge at the tunnel; as characteristic geometry of DTM, which is modeled outside off processing the TIN (URL 7).

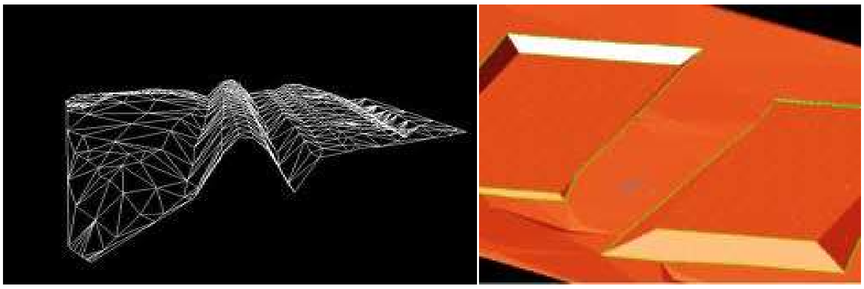

Fig. 4. View on characteristic geometrical feature of DTM (URL 7).

3.4 Processing of DMR and creation of DTM

In the initial stages in creating of DMR, prior to any specific interventions in DMR shall be conducted roughly processing of data model. After this procedure takes place follows the analysis and comparison of the results obtained by TIN (by automatic processing of the software application itself). These obtained results will be analyzed in detail such as: analyzing wrong connecting elements on TIN and subsequently prepare the way that these data will be formulated till its finalization from outside domain of automatic processing of DTM. Our interventions should serve for as accurate and as precise assessment based on factual situation, whilst the reprocessing (removing the wrong connections in TIN) this could further enhance and improve modification of the DMR, and finally create the DTM. In making decisions we need to be very careful and, if possible, to be able to immediately recognize mistakes on connections in the TIN model, and also be able to recognize the real geometry shapes of characteristic structures of their forms, as well as characteristic parts of the terrain itself .

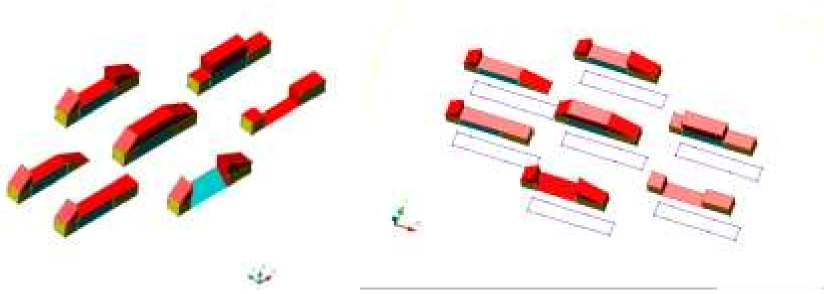

Fig. 5. Example of possible combinations and interpretation of possible connections triangle, with characteristic geometric objects or characters in the process of creating of DTM (URL 7).

For this reason, we have to prepare additional information of geometric elements, such as:

- new points
- 2D lines or 2D polylines
- 3D polylines

These data should be prepared independently. By adding these new geometric elements actually creating such a modality that through incremental elements make certain interventions on the model, we consider the ultimate vision of the modeling of the real situation of these geometric shapes.
These elements will be manually added or redrawn within the 2D situational plan or through connecting 3D points by 3D polylines (2D detail is represented as a 2D situational plan within the details of 3D points). After correcting, by adding of these additional geometric elements to the DMR model and it's redrawing (connecting the points by these new elements) can create more accurate DTM, which has to represent its factual reality in the field, and also the characteristic shape on the ground.
By completion of above-mentioned steps, it is already finished work on the automatic processing of getting the TIN, as well as getting the DTM. Finalization of such DTM model is ready to be used for the next phases or other actions for urban design planning.
3.3.2 Preparation of the final DTM, for a different kind of interpretation.

When DTM is created, the new layer will be formed for creation of contour lines. Created contour lines will be represented as 2D polylines and 3D polylines also and by equidistance unit (requested in advance by the investor). They will be created automatically, via tools for creating contour lines from the already created DTM, and that is DTM surface. Contour lines will be presented as 3D polylines object. The explosion of the 3D polylines object will result the 2D polylines which at the same time represent requested contour lines in 2D situational plan. Another additional layer at this stage will be created, to represent the 2D contour lines and also another layer which will represent a shaded surface of model of terrain.

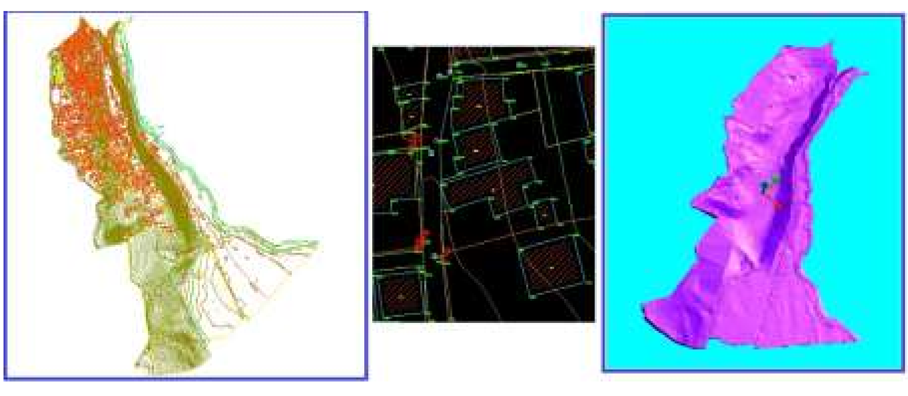

Fig. 6. 2D Situational plan with contour lines and 3D Mesh Surface DTM (URL 7).

4 Preparing data processing to create objects in the third dimension (3D objects).

Measured data of the fields and objects in 2D layout are represented in the dimension of Xi and Yi, while Zi is presented as textual information (interpretation of the terrain elevation) and it provides information on absolute elevation at each vertex point of 2D polylines footprint of objects. Thus, within the 2D situational plan, Hi variable of objects will represent (or display) the penetration between the building footprint and the ground of its terrain. Presenting the real geometrical forms of 3D object shall be done through an independent process, which will be displayed over the measured heights data of objects. For this reason it is necessary to prepare the additional elements of the measured and calculated data on the heights and information on number of floor for facilities. The process itself will go through certain phases or by default steps. 4.1. First phase: calculation of elevation peaks of objects (facilities) and setting of this information to the 2D situation plan of the terrain. At this stage, should approach calculating of elevation peaks of each facility. The finalized peak of elevation will be achieved by calculating the terrain quota of footprint of facility (absolute height level above the sea) with th e height of sides of the object, this derived heights will be denoted as Hn (object absolute height level above the sea). Calculated elevations Hn for each facility will be represented as textual data and will be placed in the interior of a closed 2D polylines and will represent the database objects in 2D situational plan. This procedure is carried out for the reason that in the process of programmed automatic processing through the VBA module, where this shall automatically be able to recognize that this text quota (elevation) belongs to that specific building. The module is programmed in VBA for CAD application. It works in a way that seeks a text attribute (as text element in the CAD application) inside 2D polylines, and later converting 2D polylines element in the " region " (as the region element in the CAD application), The “region” will raise from zero plan elevation on plan height Hn elevation as 3D volumetric object (volumetric stuffed body), or 3D solid element in the CAD application.

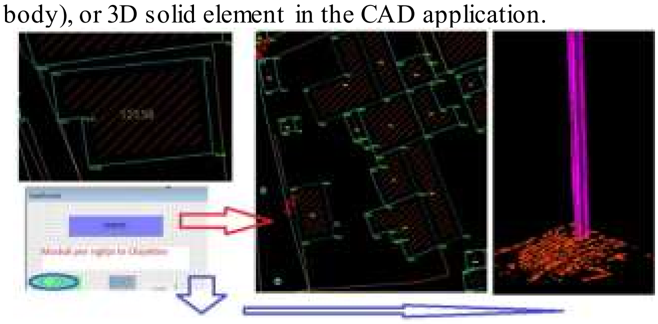

Fig. 7. Module for lifting of each object (2D closed polylines) from zero height level at 2D situation plan, to the tops (peak) of the object to be get 3D objects (URL 7).

4.1. Second phase: creation of new layer with a closed polylines for each object

Since in CAD (Computer Added Design) the only 2D closed polylines (objects as 2D polylines) are capable to be converted into the region element and by other hand by using of the regions we are capable to create such a volumetric objects. At this stage we again approach by drawing the objects with 2D polylines, if previously we did not redraw the objects at the detail of the 2D situational plan. The only condition is that the 2D polyline in 2D situation plan must be enclosed for each of our object. But this is not just about raising the third dimension of objects such as, for example, houses, buildings, or other related facilities. The 2D polylines elements of geometry in CAD applications are representing: the line segments and the curve CAD elements. The similar characteristics features for doing of 3D solid objects in CAD have also the circle CAD element. The module programmed for our case is constructed to be work through closed 2D polylines elements. 4.3. Third phase: Automatic lifting of 2D object from zero planes (plane of the base object with zero elevation) up to the height of the peaks of each of the objects This whole process is based on the idea of transforming the 2D geometry in 3D geometric mathematical bodies, i.e. filled (closed) volumetric bodies (solid volumetric object-the body stuffed by material) or opened (not filled-not closed) volumetric geometric body (body without materials or empty body). In our case it is desirable to create a filled volumetric geometric body, because it will be required for the process in the next stage (4th phase), in a way to have opportunities for calculation of the volume of objects. 4.4. Forth phase: Creating surfaces (CAD surface) - DTM as a closed body or geometric closed body (volumetric body)

When using this method, the volumetric size of the terrain must be of imaginary nature, because the irregular volumetric body can make penetration with all other 3D object volumetric bodies that are created in the process of rising of 2D polylines made in the 3rd phase. The resulting surface DTM is shown as "3D Mesh " area. To convert this to an imaginary surface volumetric body was used CAD "Lisp script" module, where by this theory will be convert a TIN network to the volumetric body. By other words from each 3D Mesh triangle of DTM will be creates a single 3D Solid body. Finally from amalgamation of each individual volumetric bodies will be created a single volumetric body and by these we created a DTM volumetric body.

4.2 Fifth phase: Creation - penetration volumetric DMT with volumetric 3D object bodies.

In order to create a realistic 3D object above the surface of DMT, we have to use an idea for separation of between of two volumetric bodies. Described in detail, it would mean, separating of volumetric DTM body from each 3D model volumetric objects. Using of this methodology ultimately will be results of real 3D objects in the field. These 3D objects are now ready to be set up on the surface of DTM. This separation of body's was carried out through a manual process.

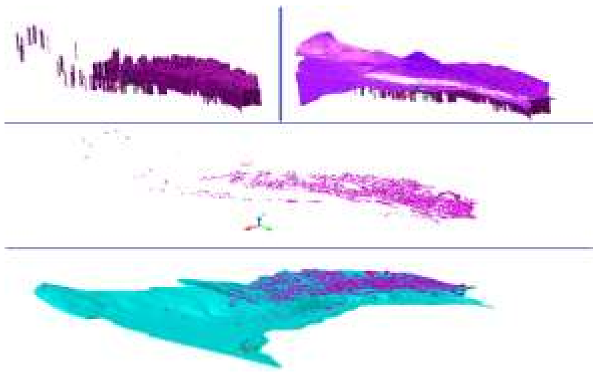

Fig. 8. Scheme of data processing through phases III, IV and V (URL 7).

4.3. Sixth phase: Displaying of 3D objects on the surface of the DTM

Within the software 3D Civil Design (version 2009) and by using the application "Raster Design" will be entered the orthophotos (with the grid of the state coordinate system Kosovaref01) for this part of the terrain. From chosen certain options, from the package "Civil design" will be processed the overlapping of ortophotos on the DTM. After this result will be entered also the 3D objects and now we begin to get a realistic view of DTM with 3D objects and overlapped orthophoto on DTM.

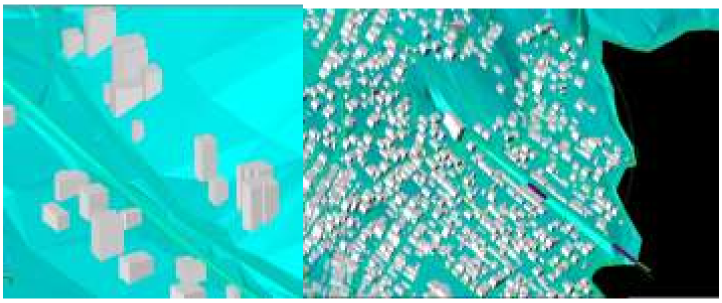

Fig. 9. Picture view of DTM with 3D objects (URL 7).

5 Visualization

Through rotation movements of positions of DTM with 3D objects at the application Civil Design can be realized the visualization of our finalized model of the city. On the visualization we can do also a classic print screens for further presentation of our city model. This method of visualization is only a primitive form of presenting of real DTM model with 3D objects.

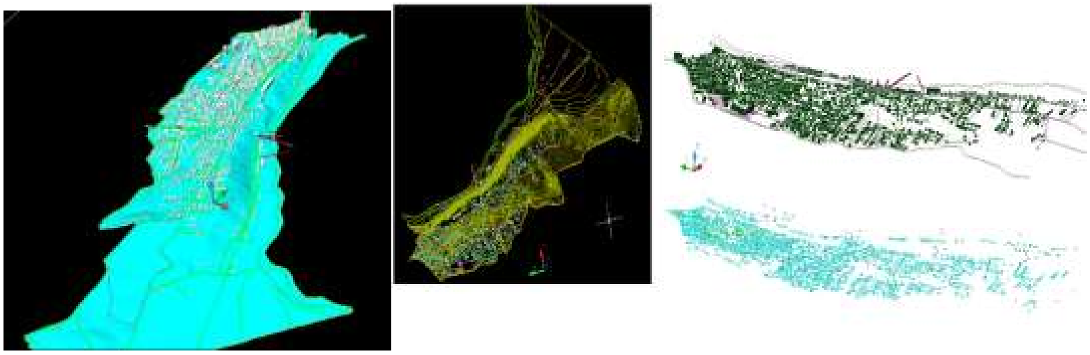

Fig. 10. Interpretation of 2D situation plan and DTM with 3D objects in the visualization (URL 7).

6 Processing of data for future preparation for the interactive 3D visualization

3D objects are presented in the form as "3ds" file format. From the CAD application, the surface of DTM will also be transferred as “3D Face Surface“, in the same format as "3ds". In order to reach the final solution for the interactive visualization, work has been carried out by using the modalities and working principles of the different tools (today available tools or software’s for visualizations). Visualization can be done by using the primitive tools which by themselves somehow can do the creation of such interactive visualization, or by those tools that are high sophisticated and aimed to do precisely visualization and interactive interpretation of complicated models. To reach the final idea, was to do a number of test combinations, by using of such existed today’s tools and applications, as the only way, to be able to make an interactive visualization of complicated models, as it is our city model. For using of each of these tools and also for a priory chosen applications, it is necessary that our DTM has to be also prepared for acceptable formats of these tools or application. Every application itself has some basic integration by which it operates, and the principles from which it works. The most appropriate and the only ones, who can do our best work, are the tools that operate on the principle of perfect graphic, and their primary purpose is aimed to do the computer games. Applications or tools as beta test which has enabled us to do this kind of interactive visualization of our city model (DTM with 3D objects), was an application called “3DRad”. This application by itself contains the integrated module for reading of the imaginaries terrains and his aim is for gamming purpose. The “3Drad” by its modules is constructed for doing the dynamically interactive interpretation and visualization of 3D objects within the terrain (only for simple imaginary terrain for games). In the cases with realistic created terrains and built from the TIN principle, it is particularly very difficult to create a real terrain data model and to be acceptable for reading by terrain module of 3Drad. At the very beginning it was very difficult how to come up with the solutions in manner that our real DTM to be read from 3DRad terrain tool. Terrain file format of 3D Rad is created based on the mathematical principle for creation of the matrix vector. Because of this reason, every mathematical triangle will be running as vector format performed from the basic mathematic functions of the plane. Applications created, with such a principle, are mostly dedicated for creation of computer games, as it, also the 3DRad aims to be for these purpose. Because of this situation, we came up with another solution, by preparing of our DTM for another file format and then to be read interactively from the other tool readers within the 3Drad. The required data format for reading of our DTM into the 3DRad was the "X" gamming standard file format. By converting of TIN (original DTM) shaped “3D Face“ to "X" file format , via the so-called "Blender" applications, we managed to create our DTM for use as terrain model of 3DRad. Using the same principles for creating of data in such a file format and also by using of other tools like “Google Sketchup”, we then also converted our 3D models of objects for the same "X" file format. At the end, entering the created DTM and the 3D object in acceptable file format to be read in 3DRad, began the operating of the first version of an interactive visualization of our city model. This would mean that over the 3DRad is much easier and simpler way can be achieved, that our model (DTM with 3D objects) will be represented as a kind of computer game. Designing of this kind of models of the cities, it is much more appropriate and easiest way for observers, citizens and investors to have better view on it and also to make analyses and for experts to brining better decision for further design implementation on urban planning.

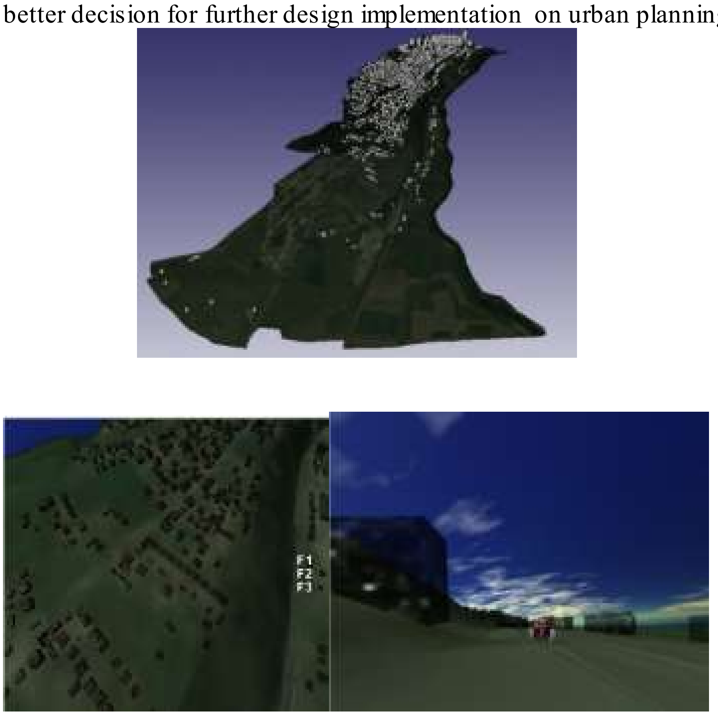

Fig. 11. Interactive visualization of DTM with 3D objects and orthophoto through 3DRad applications (URL 7).

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