# Application of 3D City Model in Spatial Planning of the City of Zagreb

**Darko ŠIŠKO, Vlado CETL, Vojkan GAVRILOVIĆ, Danko MARKOVINOVIĆ, Croatia**

**Key words**: 3D city model, spatial planning, Zagreb

**SUMMARY**

City of Zagreb has been developing 3D city model for spatial planning since 2008. The initial 3D model was created by photogrammetric mapping with Level of Detail 2 and later updates were made using airborne LiDAR data and UAV photogrammetry. City spatial planning sector was detected as the main user and developer of value added applications, while more users were detected in the fields of emergency management, environment protection, energetics, risk management etc.

Web App ZG3D for browsing, viewing and using 3D data was produced and presented in 2016, based on the existing 3d city model and considering the guidelines from previous studies. ZG3D integrates 3D data on existing buildings with 3D and 2D data layers from the fields of urbanism, architecture, topography, geotechnics, public green spaces, heritage protection, urban renewal and statistics. The aim of the project is to use and develop 3D city model in the city administration, education, science, economy, civil society and other applications.

Application of 3D city model in spatial planning of the City of Zagreb so far may be classified as 3D overlay in master land use planning, 3D building zoning in detailed land use planning, 3D modelling of new buildings during architectural competitions and 3D modelling of building interpolations in protected city core. The 3D city model has also been identified as one of the fundamental databases in the post-earthquake reconstruction process.

The City of Zagreb plans to upgrade the existing 3D city model and the ZG3D application towards the digital city twin. The main issues are upgrading and updating 3D building data and integrating live information about urban processes and activities within the 3D model of the city. With model improvements and integration with real-life data, the impact on city planning and management is expected to be even higher.

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## 1. INTRODUCTION

Spatial planning was one of the first sectors to use semantic 3D models in its daily work. In the case of the City of Zagreb, the need for better city planning and development was the main driver for production of 3D city model and Web GIS applications. The initiative for a new spatial "framework" of spatial planning emerged in mid 2000s, after the finish of large scale master planning of the Zagreb urban area and shifting the focus on detailed urban planning and city projects. In detailed planning, especially planning of already built areas, knowledge of 3D data on existing buildings became a crucial tool for efficient city planning and protection.
The model development started in 2008 by photogrammetric mapping with Level of Detail (LOD) 2, for city urban territory of about 240 km² (Figure 1).

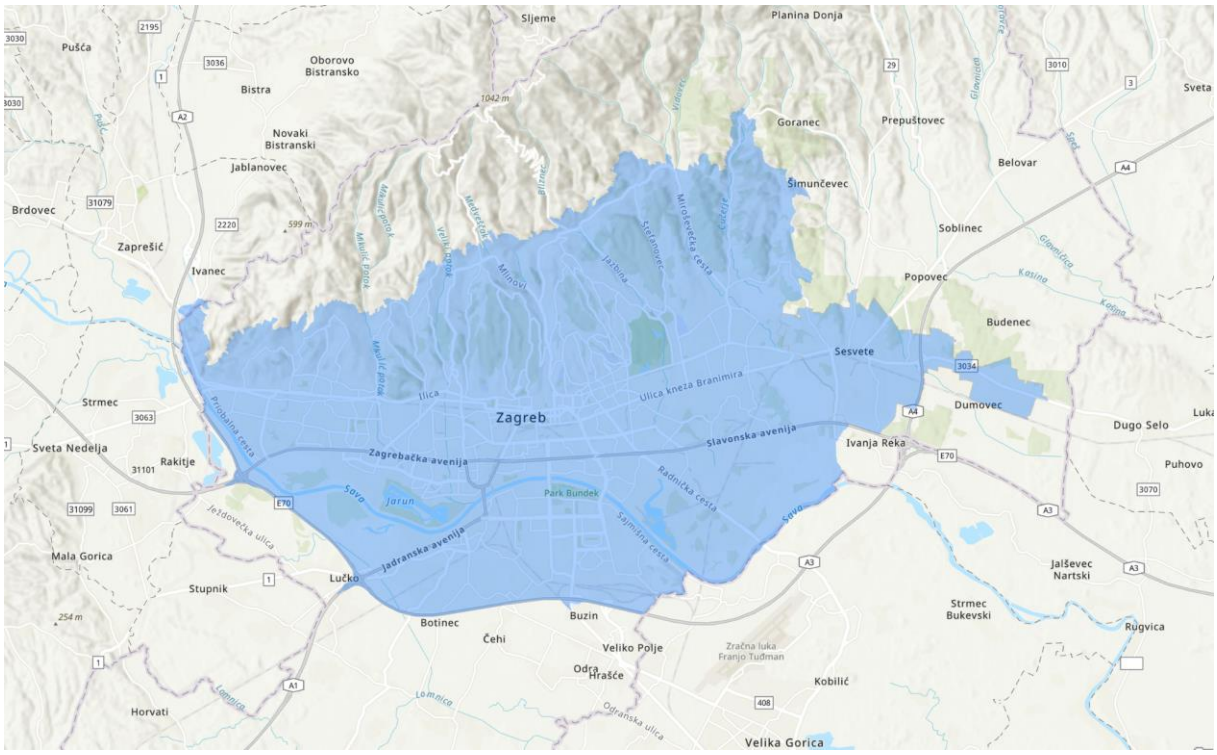

Figure 1. Zagreb urban area - borders of master (general) urban plans

In the same period, the City started preparations for usage of the model in its projects and procedures. Study on application of 3D model in city management was published in the cooperation with the University of Zagreb in 2013 (Cetl et al. 2013), containing model theory, data sources, formats and softwares, and applications in cadastre, real estate management, spatial and urban planning, heritage protection, energetics, risk management etc. There are very concrete topics were 3D city model is already or planned to be used:

- Control of geodetic documentation
- Creation of development strategies
- Implementation of urban-architectural competitions
- Creation of urban plans and detailed landscaping plans
- Traffic design
- Construction permits
- Records of protected monuments of cultural heritage
- Assessment of agricultural and forest resources
- Noise maps
- Solar cadastre
- Planning of utility lines
- Emergency simulations
- Tourist promotion
- Informing citizens.

The use of the 3D city model offers numerous potential advantages and benefits in maintaining city infrastructure, including simpler and more effective management, redundancy reduction, facilitated access to relevant information, simpler communication etc. However, it should be kept in mind that the implementation of the 3D city model and its use is not easy. It is rather a complex, long-term and evolving process that requires appropriate resources as well as appropriate organizational support.

This paper is organized as follows, after the Introduction, in Chapter 2, we provide more details on the Zagreb 3D model development together with applications. Chapter 3 provides more details on how the 3D city model is used in city planning. Chapter 4 is dealing with future developments towards digital city twin. Finally we provide main conclusions based on the development process and usage of 3D city model in Zagreb so far together with some future outlook.

## 2. ZAGREB 3D MODEL DEVELOPMENT

The initiative for the 3D model development came from geospatial data provider Geofoto Zagreb in 2008. The aim of the entire project was to produce a digital terrain model (DTM), 3D model of buildings, and a true orthophoto map. Geofoto carried out an aerial photo survey in September 2008, capturing 4,000 aerial images (GSD=8cm) with 80% intra-strip and 60% inter-strip overlap, using Vexcel UltraCam X. The virtual model was made using photogrammetric mapping of rooflines, together with DTM, aerial photography and true

orthophotos. A scale model of the city was also made using 3D print technology (Novaković 2011). The majority of the model was produced in LOD 2.

City department in charge of spatial planning took over the data only in the early 2010s, regarding slow and complicated public procurement procedures. The City set two main goals: to evaluate the quality of data and its suitability use in city planning, and to develop an online application for viewing and use of 3D city model.

### 2.1 **3D data evaluation and updating**

In cooperation with the University of Zagreb, the project of the evaluation of 3D model data was made in 2015 (Cetl et al. 2015). The project included data analysis, data quality assessment, data conversion, data transformation and testing, data visualization, building volume analysis and guidelines for updating, presentation and standardization.

The quality assessment was done in line with ISO 19157 Data Quality standard. The main findings were lack of completeness in some areas, logical consistency issues (data formats) and temporal issues (missing objects). On the other hand positional and thematic accuracy were ok. Standard deviation for positional accuracy was ± 20 cm and for heights ± 40 cm. Also the usability of the model was assessed very good. The analysis provided a good base for further improvement of the model.

The initial model in 2008 was made for the entire urban area of the City, but the data updating is based on a fragmented project approach. The reason was partly lack of appropriate funding, and also with the idea to use all new 3D data from various city projects. Updates were made using data from 2012 LiDAR and aerial photogrammetry, and 2016, 2019 and 2020 UAV photogrammetry.

### 2.2 **ZG 3D Web App**

In 2016 Web App "ZG3D" for browsing, viewing and using 3D data was produced and presented, based on the existing 3d city model and considering the guidelines from previous studies. ZG3D (https://zagreb.gdi.net/zg3d/) integrates 3D data on existing buildings with 3D and 2D data layers from the fields of urbanism, architecture, topography, geotechnics, public green spaces, heritage protection, urban renewal and statistics. The aim of the project is to use and develop 3D city model in the city administration, education, science, economy, civil society and other applications. The application allows user to view layers and basemaps, customize data display, object selection, 3D and 2D measurements, visibility analysis, cross-section creation, shadow display and address search (Figure 2).

The latest version of the ZG3D application was released in December 2021. Provider of the application is geo IT company GDi Zagreb and it is based on ESRI technology. Custom JavaScript web application was built with ArcGIS API for JavaScript 4. x. It supports core

location-based functionality such as basemap layers, geocoding, and elevation services. ArcGIS data hosting services are used to access data in the cloud such as feature and image tile services.

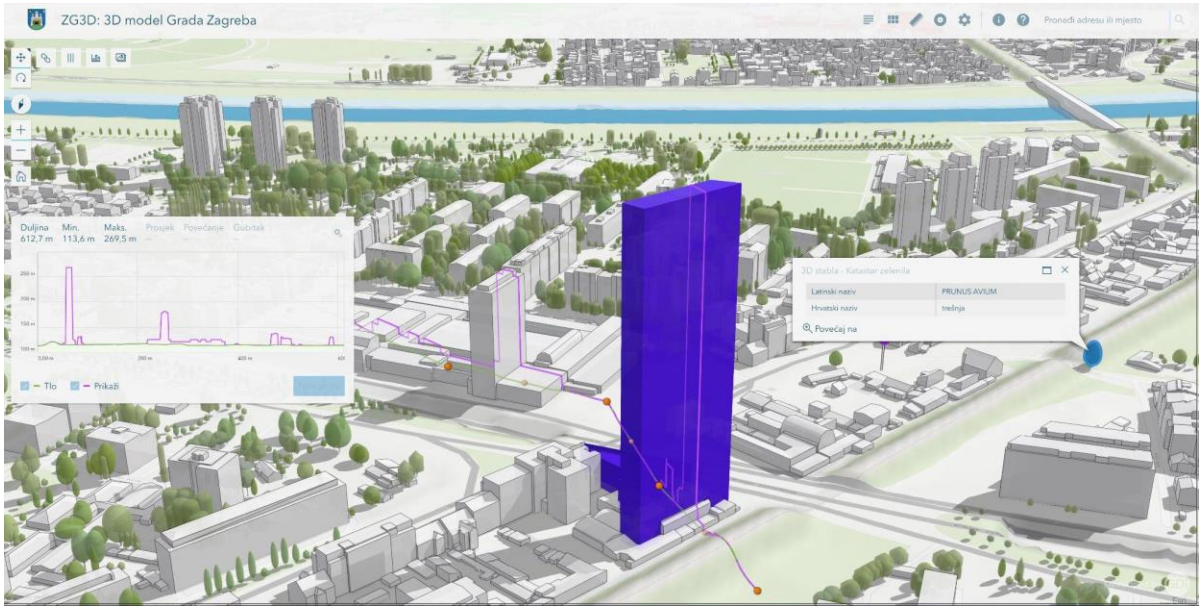

Figure 2. ZG3D Web Application

## 3. 3D MODEL IN CITY PLANNING

Zagreb city planners successfully adopted digital spatial technologies in 2D form during the 1990s and 2000s, both in spatial plans production and presentation to the wider public. New digital basemaps and spatial data services allowed planners to make more informed decisions, GIS analysis gave new opportunities in development of spatial scenarios, digital plans were presented to the public via web GIS applications (https://geoportal.zagreb.hr/) and spatial plans became a part of spatial data infrastructure on local and national level. Still, information on the city terrain, surfaces and building heights and volumes were extracted mostly from attributes of 2D data.

Next step in city planning in the information age is 3D urban planning. Precondition for 3D planning is the existence of a 3D city model, appropriate planning tools and qualified planning stuff. Application of 3D city model in spatial planning of the City of Zagreb so far may be classified as:

- 3D overlay in master land use planning
- 3D building zoning in detailed land use planning
- 3D modelling of new buildings during architectural competitions
- 3D modelling of building interpolations in protected city core.

Overlay in master land use planning with 3D city model is one of the basic ways of virtual world visualization for urban planning and development (Jonas 2014). From this overlay planners may e.g. check proposed building regulations with existing local situation and adjust

it better with existing building heights and volumes. Combination of land use map and DTM can also be useful in urban planning of hilly and mountain areas, considering terrain limitations and landslides (Figure 3).

Figure 3. Overlay of land use map, DTM, 3D model and landslide data (Pantovčak, Zagreb)

When it comes to detailed urban planning, the 3D city model becomes an inevitable tool for evaluating existing buildings and for designing and presenting building regulations to the general public. 3D building lines can be presented to the local population and the city administration as volumes showing the possible future dimensions of buildings in a 3D environment (Figure 4).

Figure 4. 3D building lines and volumes interpreted from detailed urban plan (Trnje, Zagreb)

Architects were one of the first users of 3D data, especially to show the impact of planned buildings on their environment. In the past, these visualizations were made by approximating the heights and shapes of buildings and without an accurate spatial reference. 3D models of cities have given architects those features that are missing, along with the ability to integrate with all other spatial data. After the introduction of ZG3D, Zagreb architects began to use it for analytical and visualization purposes in architectural competitions and for the design of building interpolations in the city center (Figure 5). This approach enables the creation of better and more accurate spatial solutions and generally informed decision-making in urban planning.

Figure 5. Spatial analysis and final architectural design (Lang square, Zagreb)

An earthquake measuring 5.5 on the Richter scale occurred in Zagreb on Sunday, March 22, 2020 at 6.24 am. Many buildings and infrastructure were damaged, which changed the city landscape (Vučić et al. 2021). The 3D model of the city has been identified as one of the fundamental databases in the post-earthquake reconstruction process. A major public building reconstruction project is being run using a web GIS solution with live integration in a ZG3D application (Figure 6).

Although many improvements have been made in the last decade, there are still a number of challenges in applying 3D city model to the daily work of planners and architects. Some of the issues that need to be addressed in the future are the standardization of urban planning and architectural data, education of planning and architecture experts, and finding a sustainable model for updating data.

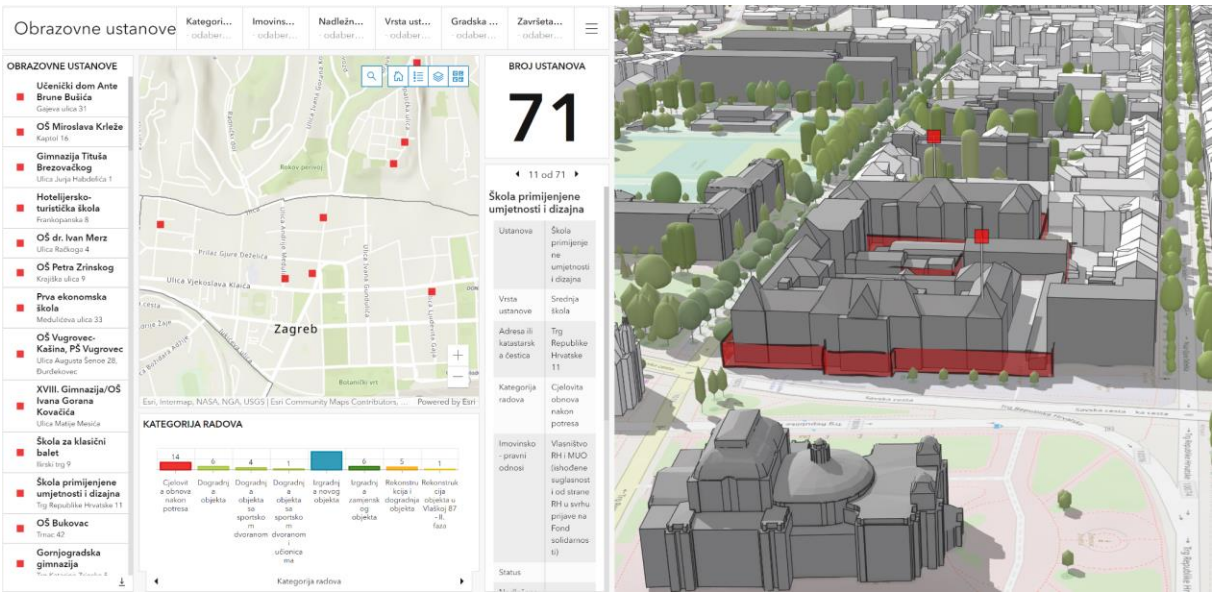

Figure 6. Web GIS and ZG3D integration in post-earthquake reconstruction

## 4. TOWARDS ZAGREB DIGITAL CITY TWIN

A 3D city model is a digital representation of an urban area and provides a fundamental building block for digital twins. They can be consumed offline and online using interactive 3D platforms and provide a wide range of analytical and visualization tools to support smart city operations. Adopting a smart city approach, with 3D city models as the base, provides huge economic benefits to cities, especially in city planning and urban design. (https://www.spatialsource.com.au/3d-city-models-the-fundamental-building-block-for-digital-twins/). Digital twins also allow urban planners to examine how proposed developments fit into and impact the area in which they're situated using real-world data. They can study the effects of development, traffic, climate change and many other situations a city must face.

Digital twin by definition is 3D virtual replicas of a given system, place or thing, which should allow cities and property owners to test out changes before real-world implementation (https://tomorrow.city/a/what-is-a-digital-twin). It is built on Big Data, huge volumes of information that can be filtered and processed by sophisticated computer models. Many cities around the world have launched plans to build digital twin cities. The rapid development of digital twin technologies has also made it possible to construct digital twin cities (Deng et. al. 2021).

Often, the challenge isn't a lack of data but consolidating large volumes of many different data types, such as those provided by Internet of Things (IoT) sensors. IoT sensors on vehicles, for example, help planners understand how and where traffic flows. This data can be used to improve pedestrian safety along certain routes, optimize traffic flow and encourage alternative

transportation in areas where such alternative forms are most viable (https://resources.esri.ca/news-and-updates/the-role-digital-twins-in-smart-cities).

The City of Zagreb plans to upgrade the existing 3D city model and the ZG3D application towards the digital city twin. At the moment, there are two main issues: first, upgrading and updating 3D building data, and second, integrating live information about urban processes and activities within the 3D model of the city. After the model is updated, a new process of further updating is considered, linked to the process of use permits for new buildings. As far as live data sources are concerned, many projects of smart cities in transport, waste management, environmental monitoring, etc. are underway. The future digital city twin will serve as the basic infrastructure for further development of the smart city.

## 5. CONCLUSIONS

3D city models are the basic building blocks for digital twins and smart cities. They provide huge economic benefits to towns and cities, especially in town planning and urban design. Using interactive 3D platforms, architects and planners can better understand new building design in context, assess their impact and restrictions, anticipate urban developments, and communicate findings to stakeholders in a very intuitive way.

The city of Zagreb started with the development of 3D city model back in 2008. The model was improved and updated over the years in accordance with new technologies. The model is used in the city for many different purposes. It is also available openly for the citizens through the Web App “ZG3D”. Even very useful for different purposes, in order to become a real digital twin, the model should be upgraded to the higher level of details and as well updated on the regular basis. Only like this, it could support a smart city strategy.

Implementing 3D city model into the daily practice of planners and architects is a slow process, but can be achieved with a lot of collaboration, investment and capacity building. The results in Zagreb so far show that the use of 3D city model in city planning can help achieve better solutions in master planning, detailed urban planning and the development of architectural projects. With model improvements and integration with real-life data, the impact on city planning and management is expected to be even greater.

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## BIOGRAPHICAL NOTES

Darko Šiško is the assistant head of the City Office for Economy, Environmental Sustainability and Strategic Planning of the City of Zagreb, responsible for the Strategic Information and Research Sector. He holds a master's degree in geodesy and geoinformatics, and a PhD in urban planning. He has more than 20 years of experience in spatial information management, spatial planning, land management, strategic planning and smart cities development.

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