

The Benefits of a 3D City GIS for Sustaining City Infrastructure

A Bentley White Paper

Benoit Fredericque, Product Manager 3D City GIS Products
Alain Lapiere, Senior Director, Civil and Geospatial Frameworks



www.bentley.com

Introduction

Infrastructure serves as the interface between people and the world around them. It is used on a daily basis and can have a major impact on the health and well being of the global population. A case in point is the recent cholera epidemic in Zimbabwe that claimed more than 4,000 lives and was, in part, caused by the country's poorly maintained water and sanitation systems. Other issues in which the world's infrastructure has an important role to play include CO2 emissions, climate change, earthquakes, severe weather, terrorist attacks, coastal flooding, hazardous waste, and the depletion of non-renewable resources. And it is important to note that infrastructure concerns are not limited to developing economies; developed economies, including those of the United States and Canada, currently face challenges directly tied to deteriorating infrastructure.

Given that worldwide urbanization is accelerating, a significant battleground for sustaining infrastructure is at the city- and local-government levels. To effectively manage all of the geospatial and non-geospatial information associated with urban infrastructure, cities today need a 3D City Geospatial Information System (GIS).

The mission of a 3D City GIS is to support decision processes associated with the creation and operation of urban infrastructure. This infrastructure must be designed and constructed such that it balances the need for growth, development, and change with the equally critical requirement for sustainability and a palpable improvement in the overall quality of people's lives. A 3D City GIS can add tremendous value to the infrastructure project delivery process. By providing everything from enhanced visualization of future projects to more accurate and in-depth analysis of existing infrastructure, 3D-rendered models enable a more-realistic view of the world around us.



The Challenges in Sustaining a City's Infrastructure

The design of new infrastructure and the management of as-built maintenance processes involve thousands of technical and human challenges. Obtaining and communicating the information required for analysis is only part of the complexity. Multi-disciplinary experts have to collaborate frequently on infrastructure projects. (For example, structural experts will focus on the mechanical properties of a building while energy assessors will focus on building energy design, analysis, and simulation.) In addition, many of these experts will have to communicate throughout the project with the general public and municipal leadership.

Given the large size anticipated expenditure on infrastructure, it's easy to see that even marginal productivity improvements in infrastructure sustainability will lead to significant savings in national budgets.

Challenges related to infrastructure sustainability are numerous, and their relationship to the global economy is important. In a study by Booz Allen Hamilton, the authors put the worldwide budget for infrastructure sustainability between the years 2005 and 2030 at 41 trillion dollars, with 50 percent of those dollars going toward water infrastructure. Given the large size of the expenditures anticipated, it's easy to see that even marginal productivity improvements in infrastructure sustainability will lead to significant savings in national budgets.

A better understanding of infrastructure usage can also provide tremendous benefits. For example, a highway alignment designed to minimize vehicle energy consumption can reduce a city's carbon footprint and, thus, help sustain the environment.



The city of Helsinki, Finland uses its 3D City GIS in a variety of workflows. These include several multi-departmental programs such as; soil surveys, building permit processes, noise modeling, surface water flow modeling, and traffic simulation.

Sustaining a City's Infrastructure with a 3D City GIS

The deployment of 3D city modeling for infrastructure is becoming more mainstream, with some of the more popular uses being urban planning analysis, noise propagation simulations, and flood simulations. However, 3D city model creation and management is still relatively new compared to the classical 2D GIS paradigm. For example, the Open Geospatial Consortium (OGC) adopted CityGML, the first standard dedicated to 3D city model exchange, in August 2008. The relative immaturity of 3D city models sometimes results in sub-optimal workflows in which valuable information can be lost or 3D models are managed independently of 2D GIS data – resulting in duplicated efforts. When looking at detailed infrastructure projects requiring limited coverage but highly accurate 3D data, detailed surveys are conducted. These detailed infrastructure projects are also frequently managed independently, which can result in a loss of valuable information after the project has been completed. Often, surveying/design efforts are duplicated for overlapping areas and these areas are surveyed several times during the life of the infrastructure.

A 3D City GIS includes a reference model suitable for the management and geo-coordination of detailed infrastructure information as well as a 3D overview of, and detailed information on, urban infrastructure. It also provides a framework for supporting the information lifecycle from its creation to its exploitation by different stakeholders.

A 3D City GIS can be defined as an information management system suitable for geospatial and non-geospatial information. Bentley defines a 3D City GIS as a collection of functionality allowing data, users, and processes related to a city's infrastructure to be effectively managed. It includes a reference 3D city model suitable for the management and geo-coordination of detailed infrastructure information as well as a 3D overview of, and detailed information on, urban infrastructure. It also provides a framework for supporting the information lifecycle from its creation to its exploitation by different stakeholders. The main functional components of a 3D City GIS can be grouped into three categories:

1. 3D modeling and quality control;
2. Persist, manage, and serve;
3. 3D analysis and design.

3D Modeling and Quality Control

Creating 3D models requires data, techniques, tools, and effort. Depending on the municipality and the infrastructure project, different data creation techniques can be used, including aerial surveying techniques (aerial photogrammetry or aerial LIDAR); Extract, Transform and Load (ETL) processes; and terrestrial-based surveying. Whether a municipality subcontracts the execution of the 3D models or creates them in house, a good integration of acquisition techniques is required. The information management platform is needed to guarantee data traceability, quality control and management, and to avoid any loss of information.

Persist, Manage, and Serve

Persisting, managing, and serving constitute the platform of a 3D City GIS. This type of system should provide a secure, collaborative, interoperable, and scalable environment to manage all the infrastructure information, the resources, and the workflows. Practitioners would typically use specialized desktop applications to interact with the 3D city information model, while front-office users might prefer web applications or collaboration portals and field workers would need mobile devices. To satisfy such heterogeneous users, a 3D City GIS should combine flexible capabilities to serve information (e.g., using standard web services or point-to-point connection) to different users on different platforms. This includes data access as well as editing, analysis, or design capabilities.

Typically, city information related to infrastructure will have different levels of detail and be in a wide variety of data formats. The data might also have historical information accumulated and maintained from the time the infrastructure was put in use to the present.



The 3D City GIS process is dynamic and the quality of data and the end-user experience depends on connecting the acquisition, presentation and use of the data.

Persisting, managing, and serving constitute the platform of a 3D City GIS. This type of system should provide a secure, collaborative, interoperable, and scalable environment to manage all the infrastructure information, the resources, and the workflows.

The nature of this data also varies from structured to unstructured. Structured refers to data associated with a data model that describes the objects, their properties, and their relationships. Databases are typically considered to be “structured.” Unstructured data, on the other hand, refers to data without a formal data model that describes the objects related to the infrastructure. This includes Microsoft Office documents, scanned drawings, and paper. One might think that unstructured data is transient and non-essential. However, in infrastructure-related industries a huge percentage of decisions are made based on unstructured data. Therefore, it is important to take advantage of all the available information in the decision-making process and, consequently, to support the persistence, management, and serving of data at different levels of detail. This includes data in geospatial and non-geospatial forms that may be structured or unstructured.

A 3D City GIS should provide a comprehensive set of analysis, exploration, and design tools for all data types.

3D Exploration, Analysis, and Design

Making decisions requires information as well as exploration. With analysis and design tools, city infrastructure information can be used to make business decisions. Exploration will support both the process of finding (user looks for specific information) and discovering information (user doesn't know what he/she is looking for). Analysis aims at enriching the available information by computing specific measurements (e.g., the area of a parcel) or solving specific problems (e.g., compute the shortest route from point A to point B). Finally, the design process of new infrastructure generally starts from an exploration and analysis process.

The mission of a 3D City GIS is to support decision processes related to city infrastructure. A 3D City GIS should provide a comprehensive set of analysis, exploration, and design tools for all data types. Considering that the range of potential analysis needs is perhaps infinite, a 3D City GIS should provide open, ad-hoc access to its content.



The city of Copenhagen is conducting solar studies using the 3D City GIS to evaluate various street planning projects. The city compares the submitted project designs from competing bidders in full 3D, which provides an excellent visual representation of the proposed project.

Conclusion

The challenges of sustaining city infrastructure are enormous. However, a 3D City GIS can help address many of these. Bentley is committed to developing and leading the transition from traditional 2D representations of infrastructure to 3D representations. This additional dimension can increase the value of data, improve decision-making capabilities, and enable more effective communications about complex situations.

The uses of a 3D City GIS will continue to evolve, but some of the most compelling are here today. Bentley has worked with a number of municipalities, including the city of Toronto, the city of Copenhagen, and the city of Helsinki, in their deployment of 3D City GIS to solve problems here and now. Among the tasks being handled by these cities with the help of 3D City GIS are the management of utilities infrastructure, noise studies, light studies, development and zoning consultations, and flood and disaster planning.

For most municipal users, the path to building a 3D City GIS will vary depending on priorities, budgets, resource constraints, responsibility, size, and more, and implementing a 3D City GIS will likely involve technical, human, and political challenges. In addition, many adopters of this technology will see steady growth of the data through the execution of specific projects in parallel with the current 2D GIS system.

Consequently, the 3D City GIS will become a necessity for infrastructure professionals, much like the infrastructure being modeled.