International Engineering Journal For Research & Development
Vol.6
Issue 3

THE INTEGRATED APPLICATION OF BIM AND GIS IN THE PROCESS OF A SMART CITY TECHNOLOGY IMPLEMENTATION

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ABSTRACT

For several years, the concept of "Smart city" has been a major concern around the world. Through the introduction of a smart city, cities seek to improve the efficiency and security of their urban infrastructure, as well as the quality of life of citizens. The Smart City concept is based on the collection and analysis of data relating to urban development (buildings and infrastructure), as well as the environment and urban services. Because the artificial environment plays an important role in the functioning of the city and the quality of services, the smart city project should integrate this environment into its strategy. This integration requires, above all, the development of digital modelling for the city, urban infrastructure and buildings. Digital modelling should include asset data, operational data and environmental data throughout the life cycle of the systems concerned. This should also ensure interaction between the various modeling tools. This article presents a synthesis of the minimum tools used to model the city, urban infrastructure and buildings and discusses their compatibility.

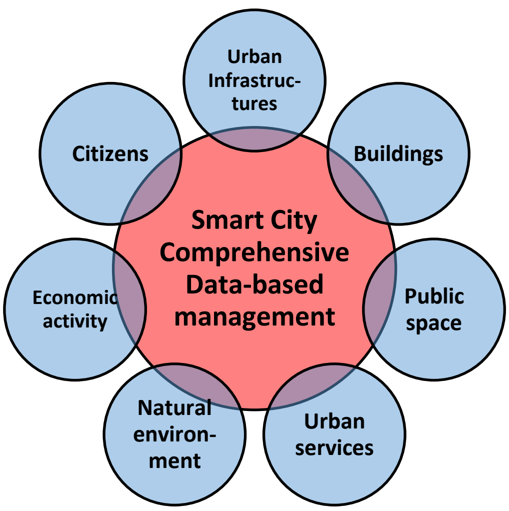
KEYWORDS: Building information modeling (BIM), Civil information modeling, Buildings management, CityGML, GIS, Smart City

INTRODUCTION

The Smart City concept opens up great opportunities for cities to meet the challenges of rapid expansion, the need for new infrastructures and buildings, the modernization of obsolete buildings and infrastructures, the provision of new urban services and the global transformation of the city into an environmentally and socially friendly city

The Smart City concept is based on the use of data relating to the physical components of the city (infrastructure, buildings, public places), the natural environment (air quality, green plantations, water resources, greenhouse gas emissions), urban services (transport, water supply, energy supply, municipal waste, education, health care, culture, sports.), economic activity and citizens (Figure 1).

Fig. 1. Smart City Concept– Data-based management of urban systems



The analysis of these data in different scales and contexts improves our understanding of the functioning of complex urban systems and increases both their safety and efficiency.

Smart management of urban infrastructure and buildings plays an important role in the effectiveness of the Smart City, as they greatly contribute to improving the functioning of the city and improving the quality of urban services. In addition, they mobilize a significant portion of City's expenses for both investment and operating expenses. The savings created by the smart city could be used to boost economic activity and improve social services.

Intelligent urban infrastructure and building management requires the collection of asset data, operational data, and usage data. Because of the interdependence of urban infrastructure and buildings, we need a comprehensive management system that collects, stores and analyzes data for urban systems (infrastructure and buildings) and then manages them in an optimal and safe way.

Various tools have been developed for digital modelling of urban systems, such as Geographic Information System (GIS) for urban infrastructures, Building Information Modeling (BIM) for buildings, Civil Infrastructure Modeling (CIM) for civil engineering infrastructures. Tools for digital modeling of the city, such as CityGML, have also been developed.

Intelligent city management requires data exchange between urban information systems. Since different tools (buildings, infrastructure, city) are used to model different urban systems, it is important to ensure their compatibility. The following document presents the tools and systems developed for digital modeling of the city, as well as its components.

The relevance of the present study is due to the fact that by the Decree of the Government of the Republic of Uzbekistan dated January 18, 2019 №48 approved the Concept of introducing „Smart city" technology in the country. In the Concept, special importance is given to conducting research and innovative work in the field of „Smart city" technology implementation.

MATERIALS AND METHODS

1. 3D City Model.

A 3D city model called Virtual 3D City Model is a digital city model that includes 3D digital modeling of common urban systems, such as buildings, landscapes and streets, as well as any corresponding object in an urban environment.

A 3D model of a city stores data related to urban systems in a structured and multidimensional form. This facilitates the analysis and management of a complex urban system. For a 3D city model that supports 3D geometric descriptions of urban systems, as well as related semantics information [5], an explicit XML-based exchange format will be defined.

The CityGML model includes 5 discrete scales (Levels of Detail, LoD) (Figure 2):

• LoD 0 Regional, landscape model: 2.5D Digital terrain model, 3D landmarks.

• LoD 1 - City / site model Prismatic buildings without roof structures.

• LoD 2 - City / Site Model: Simple buildings with detailed roof structures.

• LoD 3 - City / Site Model: Detailed architectural models, landmarks.

• LoD 4 - interior model: architectural models - "Walkable"

The current generation of digital 3D models includes databases that store any kind of spatial urban data with their geographical location. New models are not just the digital geometry of traditional models, but large-scale databases that can be visualized in a 3D environment. The model could capture and visualize data in real time using smart sensors and other available data and information. The built environment is constantly updated in terms of its staff, activity and built environment. City leaders as well as users can have an idea of urban systems and their environment. This can lead to improved functioning of the city and quality of life.

The virtual city model is used in many urban applications [6], such as geoimaging, visibility analysis, 3D cadaster, outdoor navigation, urban planning, energy demand assessment, emergency response, crisis management, lighting modeling, air quality, accessibility analysis, flood mitigation, green space management and facility management.

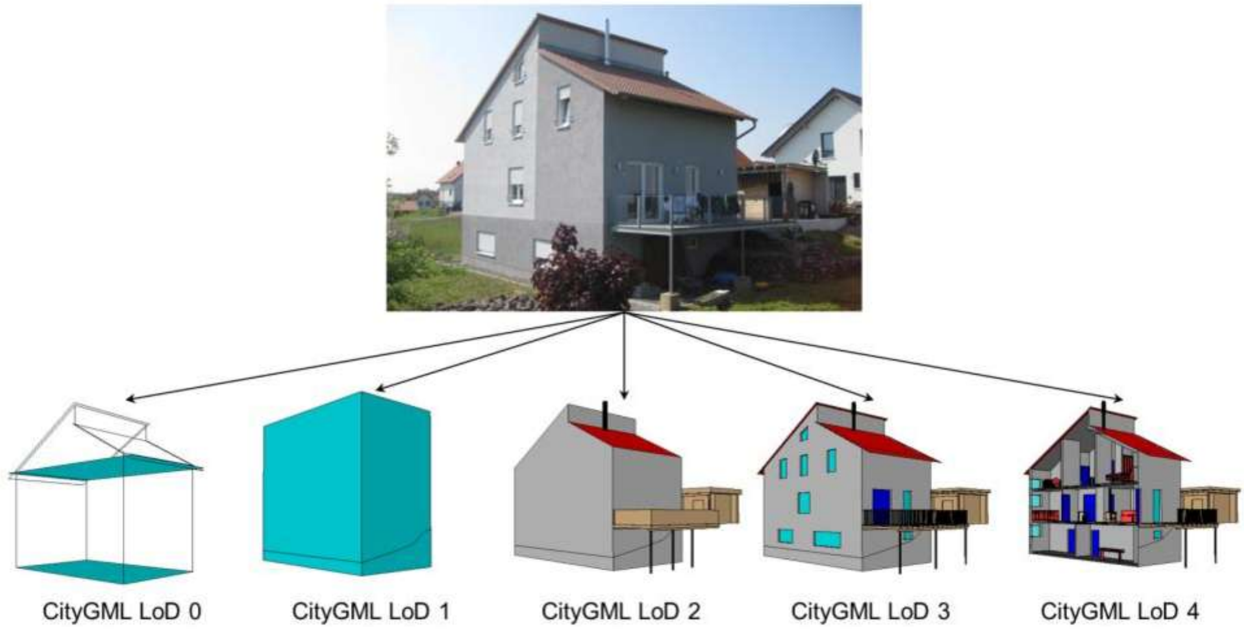


Fig.2. Representation of a building using Lod0- Lod4

2. Digital Buildings Modeling

Digital building modeling is mainly carried out using Building Information Modeling (BIM), which is a common source of knowledge for building information, which is a reliable basis for decision-making during its life cycle, from the earliest concept to demolition. BIM guarantees cooperation between stakeholders of the object throughout its life cycle (Figure 3).

Fig.3. Flow of BIM model data in the design-build-operate project lifecycle

BIM is a single virtual building model that combines technical information (architectural, structural, and MEP model), construction process, maintenance, repair, modifications, and deconstruction into a digital file. It includes a description of the relationships between objects and their properties [7]. In the BIM model, each simulated object contains information about itself, as well as information regarding its relationship to other objects, making the digital model effective for modeling (thermal, construction process, cost...).

In the BIM model, information is present in one electronic file, therefore, the object manager does not need to search in the document package [7]. At any time, the database provides instant access to any technical information of any hardware or component, and allows you to quickly find and execute solutions.

BIM information is divided into three categories; Corrective, warning and status-based [8], including information related to maintenance checks, installation and repair procedures, child cots and product replacement guarantees, and product lifecycle BIM provides information on the current status of any building component, as well as its history, such as previous maintenance, repair, or replacement [9].

5D BIM combines the building information model (3D), time (4D), and cost (5D). This model can be used through Virtual Design and Construction (VDC) for support and business purposes.

BIM offers powerful 3D visualization tools that enable you to imagine any component of a building, its history, and relationships with other buildings. This allows a virtual visit to the building and its equipment. This possibility is particularly useful during the design phase of the building, as well as during its construction and management [10].

3. Geographic Information System (GIS)

The Geographic Information System (GIS) (Figure 4) includes tools for creating, managing, analyzing, and visualizing georeferenced data related to civil and urban infrastructures as well as their built and natural environments.

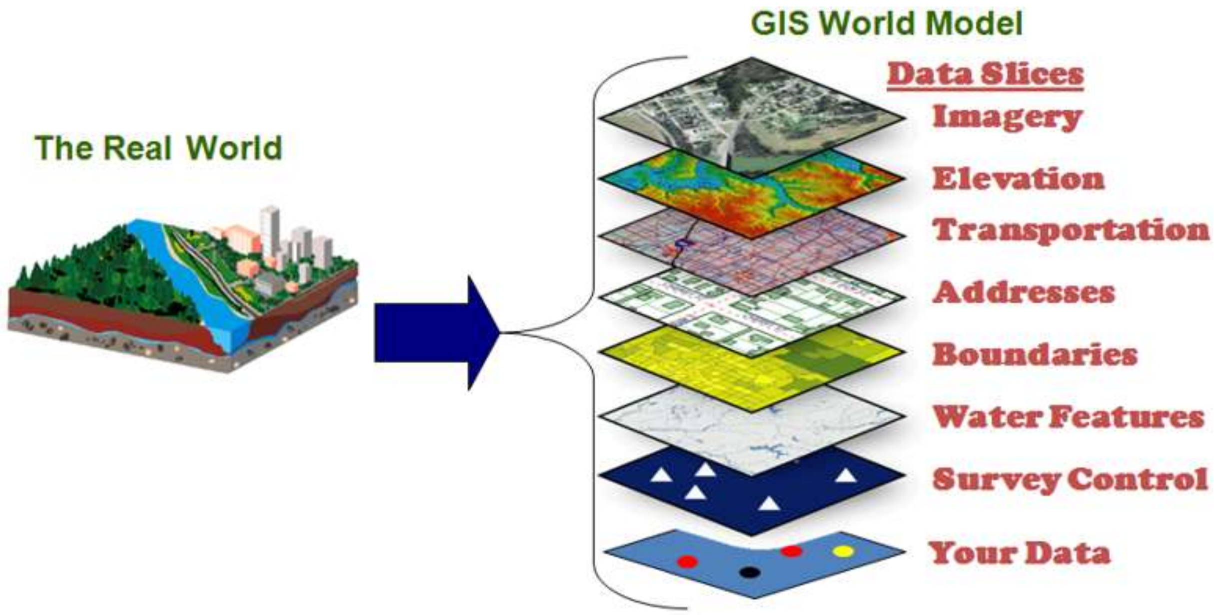


Fig.4. Geographic Information System (GIS)

It provides an integrated environment to conduct engineering, safety and environmental analyses. It enables engineers and managers to turn data into operational information, useful for the optimal and safe management of infrastructures during their lifecycle GIS offers also high capabilities for 2D and 3D interactive visualization of dynamic data, that collected by smart sensor or any other ways.

4. Civil Information Modelling (CIM)

The Civil Information Model (CIM) is used for digital modeling of civil engineering infrastructure (roads, bridges, tunnels, dams, embankments) in order to manage their life cycle. CIM aims to create 3D geographic models for civil infrastructures with multiscale, geometric, semantic, dynamic objects related to infrastructure components. It could be used to develop the transport infrastructure of the city metro, bridges, roads, railways, tunnels, airports, ports, harbors, sources of electricity, oil and gas.

The Civil Information Modeling (CIM) combines the use of digital modelling systems such Geographic Information System (GIS), BIM, CityGML and specific tools developed for modelling urban and civil infrastructures, such as Esri's ArcGIS Pro, City Engine, Autodesk Revit, InfraWorks, Structural Bridge Design, 3ds Max, RM Bridge, Power Rail Track, MXRAIL, Power InRoads, PowerCivil, WaterCAD, SewerCAD, SewerGEMS and StormCAD.

RESULTS AND DISCUSSION

Interoperability between software and digital tools designates their capacity to exchange information via a common set of exchange formats without any degradation in the quality of these information. Interoperability constitutes a key issue for the use of digital modelling tools within Smart City projects.

Works on the interoperability between GIS and BIM models focused on the use of their popular standards IFC (Industry Foundation Classes) and CityGML, respectively. The integration process between IFC and CityGML involves semantic filtering, exterior shell computing; incorporation of building installation, and geometric and semantic refinements. A large effort was made on the compatibility of these standards. However, the current CityGML and IFC standards are still not sufficient to support the structure information of the entire built environment lifecycle for urban and infrastructure projects [14].

Different integration methods between GIS and BIM are proposed [14]:

1. Manual or semi-manual conversion, translation and extension of existing standards;
2. Semantic web technologies;
3. Services-based methods;
4. Application focused methods case by case.

CONCLUSION

The Smart City concept offers great opportunities to improve efficiency and quality of life in cities. It is based on the collection and analysis of data relating to urban development (buildings and infrastructure), as well as the natural environment and urban services. Since buildings and urban infrastructure play an important role in the work of the city and as a service to the population, any smart city project must integrate them into its strategy. This integration requires building multi-scale city modeling with digital models for the city, urban infrastructure, and buildings.

Today, various modeling tools are available to model the urban system, such as CityGML for the city's 3D virtual model, Building Information Modeling for managing buildings throughout their lifecycle, and Geographic Information System (GIS) for infrastructure management. These systems offer powerful tools for implementing the Smart City project as part of comprehensive multi-dimensional and multi-domain approaches and business models.

Important efforts are being made today to:

1. Enhance BIM capabilities from the interior to the exterior (infrastructure and natural environment).
2. Enhance GIS capabilities for the interior (building).
3. Interact between tools used in modeling the interior and exterior environments to build an integrated city model.

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