The Convergence of Architectural and Engineering Design and GIS: Implications for Emergency Response and Urban Planning

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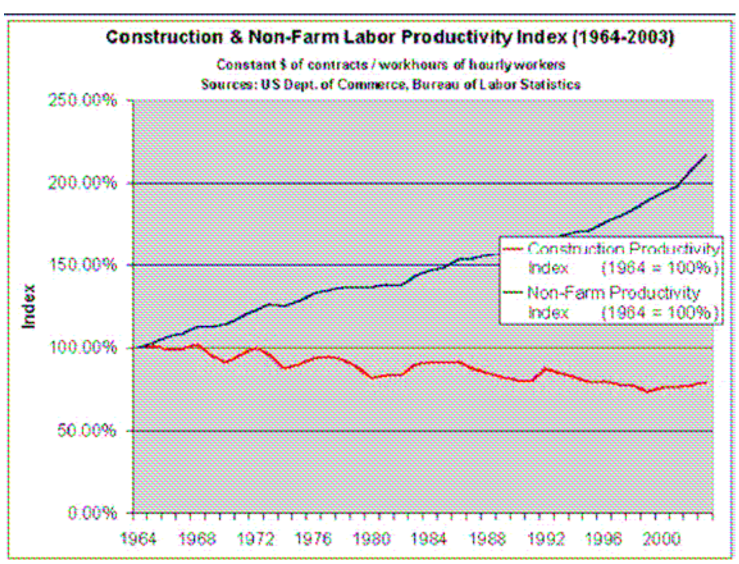
Abstract

Convergence is occurring in the fields of architectural and engineering design, construction, and GIS. The primary goal is to ensure that everyone working on a building, road or highway, and infrastructure project has a seamless flow of design information. The primary business drivers for this transformative technology advance are productivity and efficiency in the design, construction and facilities management industries and improving the performance of facilities over their full life-cycle. The integration of the different disciplines of architectural design including building information modeling (BIM), civil engineering, structural engineering, mechanical engineering, and GIS is being enabled by technological advances in 3D visualization environments for gaming, model-driven design, 3D CAD, 3D-enabled relational database management systems, and the automated capture of 3D cityscapes from aerial overflights. These technical advances are making it possible to integrate architectural and engineering designs (drawings) with imagery and other GIS data in a single 3D visualization environment that has important implications for emergency responders and urban planners.

Introduction

Statistics collected by the Bureau of Labour Statistics indicate that the productivity of the construction industry has declined by over 20% since 1964, whereas non-farm labour productivity has increased by over 200% in the same period.



Traditionally disciplines such as architecture, structural engineering, construction, civil engineering, and GIS are classic information silos. Each has maintained its own information island comprised of design applications and data. This has created a nightmare for emergency planners and responders, urban planners, and others who need immediate and seamless access to urban terrain including building interiors and exteriors, roads an highways, and above ground and underground utilities.

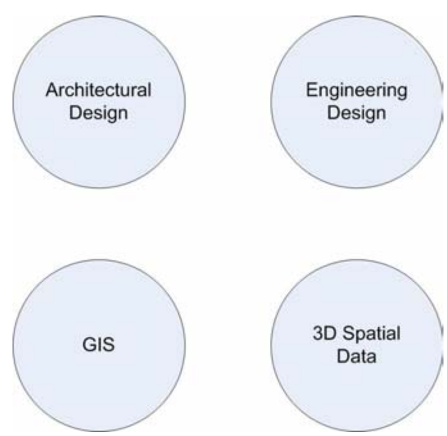
Several years ago the National Institute of Standards and Technology (NIST) commissioned a study to attempt to quantify the efficiency losses in the U.S. capital facilities industry resulting from inadequate interoperability including design, engineering, facilities management, and business processes software systems and redundant paper records management across the entire facility life-cycle. $15.8 billion in annual interoperability costs were estimated for the capital facilities industry in 2002. In addition additional significant inefficiency and lost opportunity costs associated with interoperability problems were identified that were beyond the scope of the NIST analysis which suggests that the $15.8 billion cost estimate developed in the study is likely to be a conservative figure. It is interesting that it was determined that two-thirds of these costs are borne by owners and operators, predominantly during ongoing facility operation and maintenance.

Technologies

Recently, there have been signs that the he capital facilities industry is changing with the introduction of new information technology, standards for interoperability, and revolutionary techniques for data capture and distribution. These include high resolution photogrammetry including aerial, terrestial, and close range, LIDAR and laser scanning, high resolution earth observation visual and radar satellites, spatially-enabled relational database management systems, building information modeling (BIM), 3D CAD, 3D visualization technology including gaming technology, consumer-driven Web 2.0 collaboration technologies such as Google Earth and Microsoft Virtual Earth, and BIM/CAD/GIS interoperability. Together these technologies have the potential to dramatically improve the efficiency of the construction industry and to streamline historically fragmented operations.

Facility Lifecycle

The traditional facility lifecycle involves planning, architecture, engineering, construction, operations and maintenance, and decommissioning. Facilities include buildings, highways and roads, network infrastructure such as telecommunications, power, water, wastewater, and gas networks There are many different disciplines with discipline-specific software applications that are required to build and maintain a building or a network. Each forces users to re-model



the building or network every time – focusing on the express role each discipline plays in the lifecycle. For example, in the case of a building, different organizations are responsible for designing the building structure, installing the infrastructure such as water, power, h/v and communications, preparing the building site, and choosing the building site. The disciplines involved are typically land developers, architectural firms, heating and ventilation firms, plumbers, telecommunications and utility companies, and road departments of local governments to name a few. The software applications they use include architectural design applications, civil engineering applications, land development applications, geospatial applications. Traditionally each discipline has been isolated from the other and each has maintained its own silo of design and engineering information. This has created a night mare for emergency planners and responders and others who need immediate and seamless access to building interior and exterior, road, and geospatial information. For a long time, this was how things were done. However, the facility lifecycle, whether we are talking about a building or a telecommunications network, is being compressed. In addition organizations are much more aware of the costs of operating and maintaining facilities, which over the lifetime of the facility are often 90% of the total cost of the facility. Often the information that is available is in the form of paper construction drawings, which are difficult to access and require trained personnel to interpret. At the time of an emergency, there is little time to sift through mounds of paper drawings to find the one that shows the ductwork or plumbing on the 25th floor, where the emergency is occurring.

Building Information Modelling (BIM)

Building information modeling (BIM) is the creation and use of coordinated, consistent, computable information about a building project in design—information used for design decision making, production of high-quality construction documents, predicting performance, cost-estimating and construction planning, and for managing and operating the facility. Building information modeling involves the creation and use of coordinated, internally consistent, computable information about a building project in design and construction. The ability to keep this information up-to-date and accessible in an integrated digital environment gives architects, engineers, builders, and owners a clear overall vision of their projects and contributes to the ability to make better decisions faster—helping raise the quality and increase the profitability of projects. BIM includes geometry, spatial relationships, geographic information, quantities and properties of building components (for example manufacturers' details). BIM can be used to provide visibility into the entire building lifecycle including the processes of planning, design, construction, and operation and maintenance. Quantities and properties of materials can be extracted, scopes of work defined, and workflows tracked.

Standards

NBIMS

The National Institute of Building Sciences (NIBS) defines a BIM as a digital representation of physical and functional characteristics of a facility. A basic premise of BIM is collaboration by different stakeholders at different phases of the lifecycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of the stakeholder. The BIM is a shared digital representation founded on open standards for interoperability.

The mission of the National BIM Standard Project Committee is to improve the performance of facilities over their full life-cycle by fostering a common, standard and integrated life-cycle information model for the A/E/C and Facilities Management industry. This information model will allow for the free flow of graphic and non-graphic information among all parties to the process of creating and sustaining the built environment, and will work to coordinate U.S. efforts with related activities taking place internationally. The US National BIM Standard (NBIMS) has been developed by NIBS and is designed to promote the business requirement that this model be interoperable based on open standards.

IFC

The International Alliance for Interoperability (IAI) is an alliance of organizations dedicated to bring about a coordinated change for the improvement of productivity and efficiency in the construction and facilities management industry (*Building Smart*). The IAI supports national-industrial programmes that aim to change the organization, process and technology of the facility construction industry. The IAI has developed the *IFC/ifcXML Common Model*, also known as Industry Foundation Classes, which is defined using an XML schema.

OGC OWS

The OGC Open Web Services standard includes Web Mapping Service (WMS), Web Feature Service (WFS), Geographic Markup Language (GML), and other services.

BIM/CAD/GIS Convergence

One of the most exciting things that is happening in the design software world is the convergence of architectural design, engineering, land development, civil engineering, construction, and geospatial disciplines, commonly referred to as BIM/CAD/GIS convergence. The objective of BIM, CAD, and GIS integration is to develop a framework of interoperability across the lifecycle of building and infrastructure investment involving design, construction, and operation. The business drivers for this transformative technology advance are productivity and efficiency in the construction and facilities management industry, and improving the performance of facilities over their full life-cycle. The goal is to ensure that everyone working on a designing and building a project has access to a seamless flow of design information. Project managers and other staff will have at their finger tips a seamless view of all the design and geospatial information they require.

Convergence also means that during the post-construction phase of a facility the ability to integrate data from different applications and disciplines provides important benefits for emergency responders and maintenance staff. Emergency responders will be able to have immediate and seamless access to infrastructure data inside, outside, and underneath urban structures to enable them to deal rapidly and effectively with emergency situations.

The good news is that most, if not all, of the basic geometric data that is required often already exists in precision digital form, as architectural plans in the form of CAD drawing files, network infrastructure databases, and geospatial vector and raster data. Increasingly design data is bring captured in the form of intelligent databases which are model-based, for example building information models (BIM), and incorporate the concepts of classes of objects, each class having a commons set of properties, relationships between object, rules for relationships between classes, and styles which determine how to render each class of object.

To leverage this data, it needs to be integrated into, a single, interactive model supporting 3D visualization so that you can visualize and analyze all aspects of the facility, inside, outside, and underneath, quickly and easily. This can be achieved if the integrated model is intelligent, for example, recognizes different classes of objects such as skeletal structure, walls, floors and ceilings, plumbing, heating and ventilation, telecommunications and utility networks, and terrain.

The objective is to integrate the widest range of precision data – including computer-aided design (CAD), geospatial (GIS), 3D modeling, architectural, and subterranean utility infrastructure data – to deliver a precise synthetic environment that can be used to exploit the inside (utilities, HVAC systems, furniture, elevators, walls, doors, windows, and structural details), outside (aerial utilities, full city blocks of 3D detail, road access), and under (underground water, wastewater, gas, power, and telecommunications systems) of an urban location and make this available in a variety of visualization engines, including commercial gaming engines. The key is to leverage the precision data that most owner/operators already have and to re-use across the entire facility lifecycle.

The integration of model-driven design, building information modeling (BIM), 3D visualization, CAD, geospatially-enabled relational database management systems (RDBMS), and other geospatial technology has important implications for facility operations and maintenance, urban planning, and emergency planning and response. We will discuss how BIM/CAD/GIS integration will impact areas requiring a crossdisciplinary approach and how organizations can begin preparing to take advantage of this major technical advance.