

# Blurring the Lines between Spatial and Geospatial: The Convergence of Construction, Engineering, Geospatial, and 3D Simulation

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## **ABSTRACT**

The world's construction industry is facing serious challenges including global climate change, aging infrastructure, a shrinking workforce, and declining productivity. One of the major challenges has been the lack of investment in R&D that has historically differentiated construction from other industries. But there are signs that this is changing. The construction industry is investing in new technologies such as model-driven design, geospatial enabling, and 3D simulation. These new technologies are already changing dramatically how we design, build, manage, and operate buildings and infrastructure.

## **INTRODUCTION**

The world's construction industry's annual spend is estimated to be US\$2.3 trillion in 2006/2007. According to research firm *Proleads* the value of Gulf construction projects is estimated at US\$2.4 trillion.

The Indian construction sector is now worth over US\$50 billion per annum and it is growing at over 10% annually. Construction accounts for approximately 6% of the Indian GDP and employs over 30 million workers. There is a fascinating statistic that illustrates how this sector has taken off in the last decade. In the 50 years since independence an average of only 11 kilometres of roads were constructed every year. Since 1997 this is now running at 11 kilometres per day. Studies suggest that the gap between wages in the GCC and robust Asian economies such as India's is closing, potentially creating a shortage of skilled labour in the Gulf.



The world's construction industry is facing serious challenges including global climate change, aging infrastructure, a shrinking workforce, and declining productivity. One of the major challenges is the lack of investment in R&D that has historically differentiated construction from other industries. Expenditures on R&D in construction range between 0.01% and 0.4% of construction value-add for OECD countries, compared to 3-4% in manufacturing or 2-3% for all industries (Andre Manseau, *Innovation in Construction*). But there are signs that this is changing. To enable architects, engineers, construction firms, and owners and operators of buildings and infrastructure to address these challenges, the construction industry is investing in new technologies such as model-driven design, geospatial enabling, and 3D simulation. These new technologies are already changing dramatically how we design, manage, and operate buildings and infrastructure.

## **CHALLENGES FACING THE CONSTRUCTION INDUSTRY**

### ***Global Climate Change***

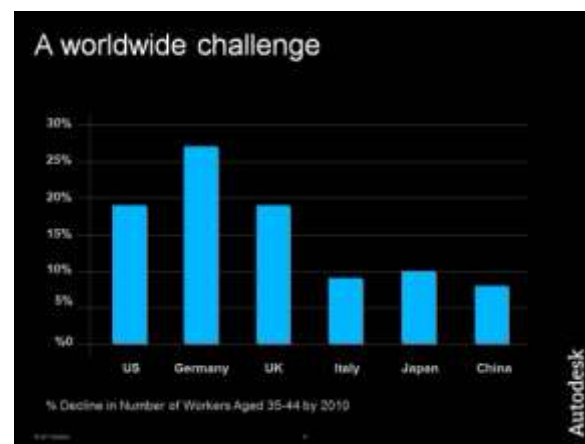
The share of Americans calling global warming the most important environmental issue rose from 11 percent in 2003 to 35 percent in 2006. In the United States alone, buildings account for 39% of total energy use, 68% of total electricity consumption, and 38% of total carbon dioxide emissions. Many of our existing buildings and infrastructure are going to have to be either replaced or retrofitted to achieve zero net carbon emissions and minimize environmental impact while at the same time yield a respectable financial return on investment.

### ***Aging infrastructure***

Every two years the American Society of Civil Engineers (ASCE) prepares a *Report Card for American Infrastructure*. In 2005 the ASCE awarded American roads, bridges, and transit a grade of D. To put this in context, the Federal Highway Administration (FHWA) reports that outdated and substandard road and bridge design, pavement conditions, and safety features are factors in 30% of all fatal highway accidents. The ASCE estimates that motor vehicle crashes cost U.S. citizens \$230 billion per year, or \$819 for each resident for medical costs; lost productivity; travel delay; and workplace, insurance and legal costs. The ASCE estimates that a total investment of \$1.6 trillion over five years is required to bring US infrastructure to good condition.

### ***Shrinking workforce***

In the US a Conference Board study predicted that by 2010, the number of workers aged 35 to 44 will decline by 19%; the number of workers aged 45

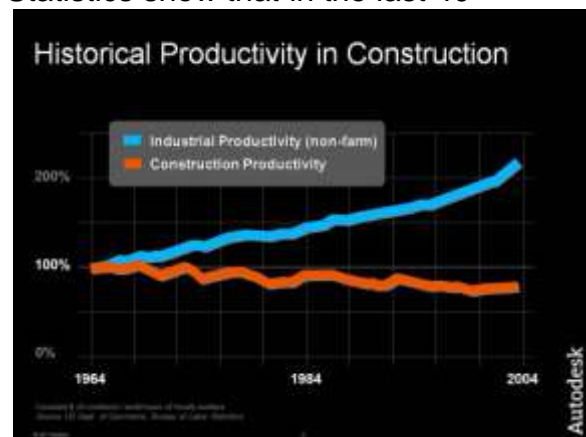


to 54 will increase 21%; and the number of workers aged 55 to 64 will increase 52%. This is a world-wide phenomenon.

A report prepared in 2004 by the U.S. Department of Labor (DOL), reported that “industry leaders noted that the construction industry is experiencing a shortage of workers. This current shortage is complicated by two trends: the growth of the industry, and the retirement of the “baby boomers.” The ETA projects that the construction industry is projected to grow at an average annual rate of 1.3 percent between 2002 and 2012, adding over one million new jobs.

### ***Declining Productivity***

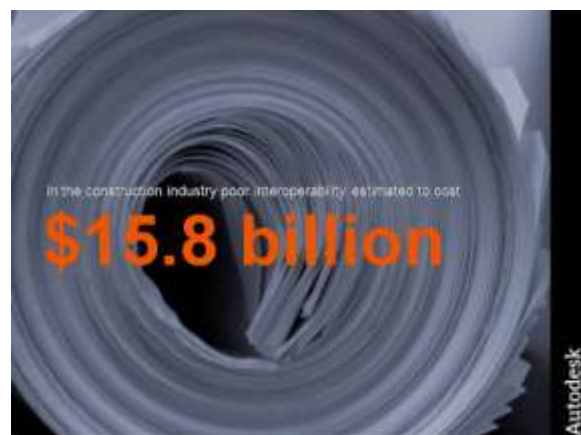
Statistics published by US Bureau of Labor Statistics show that in the last 40 years while non-farm productivity has increased by over 200% productivity in the construction industry has actually declined. In the context of the challenges already mentioned, this is creating a crisis for the construction industry.



The utility industry is facing not only a shrinking workforce, but also a loss of knowledge and experience as experienced workers retire and the industry is unable to attract younger personnel to replace them. In the utility industry the average age of the workforce is close to 50. A study by the American Public Power Association predicts that by 2010, as many as 60% of today’s experienced workers will retire. A survey of utility human resources executives by the Carnegie Mellon University Electricity Industry Center found that the aging work force is the number one concern. A recent Booz Allen study predicts that the result will be a 20% reduction in productivity.

### ***Islands of Information***

Traditionally disciplines such as architecture, structural engineering, construction, civil engineering, and GIS represent classic information silos. Each has maintained its own information island comprised of design applications and data. CAD/BIM desktop applications are the source of most of the precision design data about the world’s infrastructure data including buildings, roads and highways, pipelines, utility and telecommunications networks. In



organizations responsible for infrastructure, precision design information is critical for operations and maintenance, but the flow of this essential information between groups within the organization is typically paper-based and inefficient.

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. The NIST estimated that poor interoperability cost the US capital facilities industry \$15.8 billion in 2002. The NIST pointed out that this is likely to be a conservative figure.

## **NEW DESIGN TECHNOLOGIES**

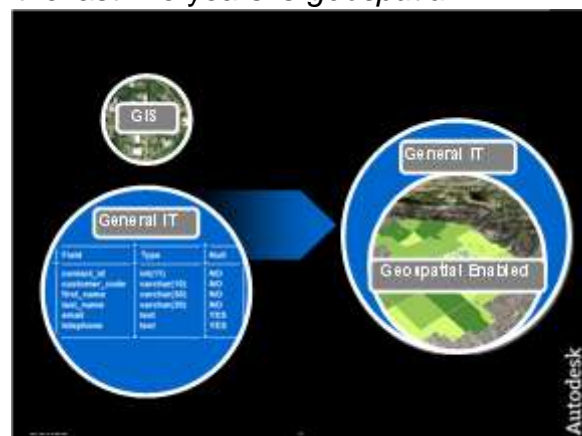
To enable architects, engineers, and owners and operators of buildings and infrastructure to address these challenges, leading members of the construction industry are investing in new technologies such as model-driven design, geospatial enabling, and 3D simulation technologies. The business drivers for these transformative technology advances are productivity and efficiency in the construction and facilities management industry.

### ***Model Driven Design***

Most of the world's buildings and infrastructure such as roads and highways, power, water and waste water, telecommunications, and oil and gas pipeline networks are designed using CAD desktop applications. Traditional CAD drawings lack intelligence because they are designed to produce a paper drawing. Model-driven design makes it possible to create an intelligent representation of real world object such as a building or infrastructure. In architectural design this is referred to as *building information modeling* or BIM, and many people in the industry, such as the US GSA, are convinced that BIMs not only reduce the costs of design and construction for new structures, but also significantly reduce the downstream costs associated with operation and maintenance.

### ***Geospatial Enabling***

One of the most important trends in IT in the last five years is *geospatial enabling*. Search engines from Google, Microsoft, Yahoo, and others incorporate geospatial technology. Most of the major relational databases including Oracle, DB2, Informix, PostGIS/PostgreSQL, MySQL, and soon Microsoft SQL Server



incorporate spatial data types. Computers, automobiles, and cell phones now incorporate GPS technology. Geospatial is also becoming a key dimension of engineering and architectural design.

Architectural and engineering design is fundamentally spatial. The only real line between spatial meaning engineering and geospatial is the type of coordinate system used. Most CAD applications are now able to support real world coordinate systems. Autodesk recently acquired coordinate system technology from Mentor Software that is widely used in the industry and plans to donate this to the open source community OSGEO, so that products outside of the traditional geospatial domain will have access to an open industry standard for real world coordinate systems. In addition the Industry Foundation Classes developed and maintained by the IAI are also being geospatially enabled as a result of an alliance formed several years ago between the IAI, which is responsible for the IFC standard, and the OGC. This is being driven by local government regulation, for example, right to light, noise abatement, view protection, and wind modeling requirements, and by green building objectives such as maximizing open space, reducing impervious cover, reducing heat islands, reducing light pollution, reducing energy use, whole building energy simulation, renewable energy systems, and daylight simulation required for LEED certification.

### ***3D Simulation***

3D simulation technology allows architects to design and experience a building or highway before it is built. Often referred to as digital prototyping, 3D simulation relies on many of the same 3D visualization and simulation technologies underlying computer games, and allows architects and engineers to convey their designs more effectively, reduces the risk of major modifications to built structures, and enables optimization of buildings and infrastructure for their full life-cycle including operations and maintenance.

### ***Convergence***

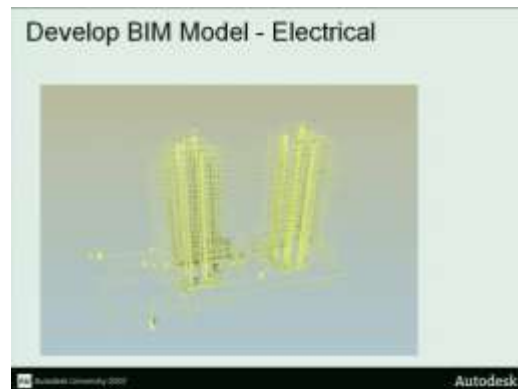
Convergence refers to breaking down the barriers between architectural design, engineering, land development, civil engineering, construction, geospatial disciplines, and 3D visualization and simulation technology. Convergence provides a framework of interoperability across the lifecycle of building and infrastructure investment involving design, construction, and operation and enables seamless access to architectural, engineering design, and geospatial data inside, outside, and under a facility.

## **NEW DESIGN TECHNOLOGIES APPLIED: WORLD FINANCIAL CENTRE BEIJING**

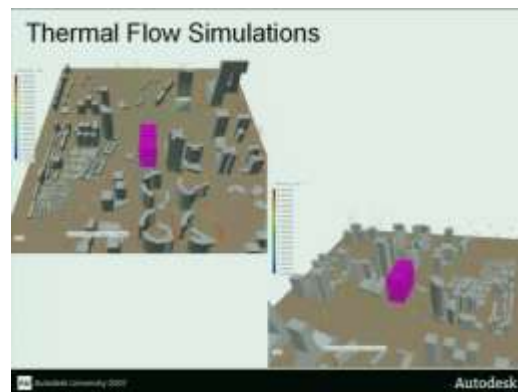
At Autodesk University last year, David Yau of Henderson Land reported on a successful project that illustrates the importance of convergence in the construction industry. Henderson developed a twin 24 four story tower building called the World Financial Centre in downtown Beijing. Because of the imminent Beijing Olympics there was a very tight timeframe for completing the structure and removing construction cranes and Henderson could not afford a delay in their schedule. In addition Henderson had an eco-objective, that the building would be LEED certified.



Construction has been called *the only industry that creates a full-scale prototype*. A major source of construction delays is what are called clashes, conflicts between different sub-system designs such as heating and ventilation and plumbing and drainage that requires redesign after construction has begun. To reduce the risk of this type of delay occurring during construction, Henderson created BIM models of the key building systems including structural, heating and ventilation, fire services, electrical, plumbing and drainage, and used a BIM application to detect and correct clashes (to within a millimeter) during the design phase.



Henderson also had to model the outside environment surrounding the building to create a thermal flow simulation to identify and reduce heat island, to run daylight simulations for daylight within the building and to model the external space around the building to optimize green space outside of the building. In this example the combination of these technologies enabled Henderson to complete the World Financial Center in an eco-friendly way on schedule and on budget.



This is a practical example of how modern architectural and engineering design technologies driven by challenges such as tight schedules and eco-friendly requirements are impacting how buildings are designed and built. Engineers and architects need to be able to model complete buildings including inside, outside,

and underground. Integrating spatial and geospatial helps the construction industry address new business challenges.

## URBAN SIMULATION

But convergence is also enabling us to realize what Roger Tomlinson, often referred to as the Father of GIS, foresaw in 1975, being able to simulate » *a model of the earth on a computer that functions like the earth, including all people, places, things and processes...we've got a tool that allows us describe the world with much greater facility than we ever have before.*« In other words by integrating architectural and engineering design, geospatial, and aerial and underground infrastructure data in an interactive 3D visualization environment we are now able to simulate an entire city.

The data that is required for a seamless view of an urban environment already exists in precision digital form, in the form of CAD drawing files, BIM models, utility and telecommunication

network infrastructure databases, and geospatial data. The objective is to re-use the precision data that was created when a facility is designed. This involves integrating

precision engineering data to deliver a precise synthetic environment that can be used to simulate 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 environment and to make this available in a seamless, easy-to-use, interactive model familiar to digital gamers that allows the user to visualize and analyze all aspects of

the facility, inside, outside, and underneath. For example, this type of urban simulation can be used to analyze the impact of a building on a utility network, how the building will shade the surrounding area at different times of the day and



year, how much daylight will be available in interior spaces at different times of the day and of the year, how noise from a nearby sports stadium will impact residents of the building, and how the building will affect traffic patterns.

The ability to simulate entire urban environments has implications for urban planners including the ability to simulate urban redevelopment projects, 3D zoning, for example, view protection (view cones and view corridors), noise abatement, right to light, wind modelling, daylight simulation, call before you dig, as well as emergency planning and first



response. For example, the ability to create a 3D simulation of a major urban development before it is constructed enables citizens to experience in a much more intuitive way than is now possible how the development will impact them; whose view will be obstructed, who will have less sun, less privacy, and so on. Cities trying to attract new business are finding that a 3D model is able to demonstrate in an intuitive manner the advantages of a particular location in terms of proximity to services such as transportation networks and hubs, recreation, and educational facilities. As another example, first responders instead of going into an emergency situation with severely limited information about the facility will be able to have immediate and seamless access to infrastructure data inside, outside, and underneath urban structures in an interactive environment that will enable them to deal rapidly and safely with emergency situations.

In summary, the integration of model-driven design, and geospatial technology with 3D simulation technologies is breaking down traditional islands of information and technology. The immediate driver for this are the challenges facing the construction industry including climate change, aging infrastructure, a shrinking workforce, and declining productivity. New technologies including model-driven design, geospatial-enabling, 3D simulation are dramatically improving the productivity of the construction industry. But these technology advances will also impact other areas benefitting from a cross-disciplinary approach such as urban planning, urban redevelopment, emergency planning, and first response.