NO. 6

VISUALIZE-SIMULATE-FABRICATE

AUTHORS
DOUGLAS OLIVER
CHRISTOF SPIELER

A look at where Building Information Modeling could take us

including **expert analysis**

> **"This technology provides a way for me to get closer to the craft. In the past, there were many layers between my rough sketch and the final building, and the feeling of the design could get lost before it reached the craftsman. It feels like I've been speaking a foreign language, and now, all of a sudden, the craftsman understands me. In this case, the computer is not dehumanizing; it's an interpreter."**
> ***Frank Gehry***

MainPlace (center), under construction in 2010, utilized BIM technology to integrate design and construction.

RENDERING COURTESY HINES INTERESTS

For the past 200 years, architecture has been driven by a process of industrialized production driven by paper drawing.

During the Industrial Revolution, new materials allowed the mass production of building components. The idea of craftsmanship quickly becomes charged and at times problematic. In the wake of the First World War, Modernism aestheticized this mass production. Now, a digital process—BIM—is making the design and construction process more efficient and, more importantly, putting architects closer to their final product.

A BRIEF HISTORY OF DIGITAL FABRICATION IN ARCHITECTURE

The history of architecture is a history of visualization and fabrication. Architects are limited by the ability to document a design and the ability of others to make it.

In the mid-1990s, the exponential development of computer power enabled digital visualization, opening new formal and architectural possibilities. Fundamentally, computers allowed designers to deploy complex forms that could not easily be depicted in two-dimensional drafting.

The architectural implication for this research was that it questioned and challenged the almost 4,000-year-old tradition of the primacy of the trabated frame of columns and beams. Almost overnight, a desire arose that sought to blur the distinction and hierarchy of roof and wall. Structure and enclosure began to fuse and become a single conceptual entity.

In the US, the "blob" period was typified by a group of young New York architects associated with Columbia University's school of architecture under Dean Bernard Tschumi. Greg Lynn's book *Animate Form* (1999) explored the potential of computers to generate multiple iterations of forms shaped by scripted and very specific performance criteria. This work quickly left behind the Cartesian structural grid and begged for new systems of structure and enclosure that were highly differentiated and systemic.

The other major thread in American architecture in the closing days of the twentieth century was the "continuous surface" project, highly influenced by the work of Rem Koolhaas in the late '80s and '90s. Like the Blob school, this work is based on the fundamental principal that floor, wall, and ceiling are one thing.

At the same time, the engineering profession was engaged in a different project prompted by the same advances in computing. In the 1930s, a handful of engineering academics began to develop mathematical methods versatile enough to handle irregular buildings, and in the '60s and '70s the commercial availability of large computers enabled their application. Computerized structural analysis came first to the world of aerospace, particularly the design of delta-winged fighter jets. By the late '60s, structural engineering firms were renting time on mainframe computers to design buildings like the Word Trade Center and the John Hancock Tower. Engineers could now calculate any system, no matter how irregular or curved.

When the IBM PC appeared in 1981, engineering analysis software almost immediately migrated to the desktop. Engineers saw their jobs change: they spent more time working with architects and more time exploring different design approaches.

The same computers appeared on the floors of fabrication shops. The steel industry was an early adopter. Steel buildings had been created in a system of pencils, measuring tape, and chalk. Every cut, every hole, every tab, and every weld on every column and beam in the building was repeatedly translated by multiple people from paper to brain to another piece of paper. The regular column grid was an architectural idea, but it was also a way to simplify the process: identical members, regular dimensions, and straight lines simplified fabrication. When the drill presses and saws were connected to computers, the information started to flow digitally, not manually, and the old limitations disappeared. The same types of changes happened to cabinetmakers, graphics shops, duct fabricators, and other industries.

Thus, the stage was set for a revolution. Architects were visualizing, engineers were simulating, and builders were fabricating. All three fields had started in different places, with different goals, but all had been changed fundamentally by computer technology.

CONVERGENCE OF VISUALIZATION, SIMULATION, AND FABRICATION

The ultimate goal is simple: complete exchange of digital information between architect, engineer, and builder. A single digital model could move through design, environmental analysis, specification of systems, budgeting, scheduling, coordination, detailing, fabrication, construction logistics, and maintenance of the complete building. The name for that goal is the "Building Information Model." BIM is here today. All of these things are happening, even if not always on the same building, today in Houston and around the globe. There are obvious efficiencies gained in the process: better owner input, fewer errors in the field, less waste on the jobsite, less risk in schedules, more energy-efficient buildings.

A casual tour through almost any school of architecture over the past decade would reveal a proliferation of mock-ups and prototypes generated by students and faculty attempting to realize new forms in architectural scale and actual materiality.

In the building industry, convergence has happened in fits and starts for a decade. In the steel industry, trade interchange standards allow an engineer's design model to be translated into a detailer's model, where it is refined and extended, not rebuilt, and then allow the fabricator's model to be translated into commands for computer driven plasma cutters, saws, and drills. On the job site, surveyors walk across building slabs with handheld units that locate building components to a fraction of an inch and computer-driven blades on earthmoving equipment precisely set the grades of highways and landscapes. Yet these have been islands of digital data, surrounded by gaps where data does not move. Disciplines do not talk and lawyers advise their clients not to tread for risk of liability.

Further convergence is inevitable. The waste and lost time that comes from the old system cannot survive in a world that prizes efficiency. Companies accustomed to optimizing every bit of their supply chain expect the same of their buildings.

We are at the beginning of a revolution as visualization, simulation, and fabrication combine. But this revolution has barely changed the shape of buildings.

MASS PRODUCTION VERSUS MASS CUSTOMIZATION

It took over half a century from the first use of iron columns in buildings to the Bauhaus; it took a decade for the desktop PC to spawn blob buildings. BIM will be no different.

The key concept in assembly line industrial manufacturing was standardization. The computerized plasma cutter, however, does not reward repetition. It is as easy for the computer to create 100 beams, cabinets, windows, or panels of unequal size as it is to create 100 of equal size. Modularity is still valid as an architectural idea, but it's not necessary for economy. So the new paradigm is not mass production but mass customization.

As early as 1990, Frank Gehry's office began to experiment with parametric modeling techniques to create 3D documents. The success of these early experiments led the team to select CATIA, design software developed for the aerospace industry, to be the centerpiece of the development process of projects such as the Guggenheim Bilbao. It allowed an irregular, curved building to be built at a cost that made it feasible.

The Yokohama Port Terminal, designed by Foreign Office Architects (FOA) for a 1999 competition, borrowed from innovations in the shipbuilding industry. For hundreds of years, ships had been assembled piece by piece in a single place starting at the bottom with the laying of the keel. With the super module approach, multiple building-sized modules can be built concurrently, then moved into place and fastened with a guaranteed precision of a few millimeters.

IT IS *NOT SUFFICIENT* TO DESIGN A BUILDING AND THEN HAVE AN ENGINEER ANALYZE ITS ENERGY EFFICIENCY; THE ANALYSIS MUST BE PART OF THE DESIGN. SOFTWARE IS EMERGING THAT ALLOWS DESIGNERS TO SIMULATE CLIMATIC CONDITIONS AND CREATE AN *IMMEDIATE FEEDBACK LOOP*.

BIM AND THE ROLE OF THE ARCHITECT

Ultimately, BIM can change the role of the architect. Kieran and Timberlake argue that BIM software had enabled the development of what they termed the "collective intelligence paradigm," allowing design and construction teams to work together in ways they never could before. They further argue that the architect ought to be at the center of this combined team: the architect can be the integrator who brings everything together. Through digital models, the architect is able to assume two tasks—coordination of systems and the definition of fabricated components—that had been done by others. BIM can place the architect closer to fabrication and construction, with a greater ability to guide and control the outcomes and thus shape the finished building.

Likewise, BIM can change how architects work with engineers. As LEED matures and begins to mandate more and more sophisticated solutions, and energy code requirements stiffen, the ability to synthesize these issues within a larger architectural "project" is mandatory. It is not sufficient to design a building and then have an engineer analyze its energy efficiency; the analysis must be part of the design. Software is emerging that allows designers to simulate climatic conditions and create an immediate feedback loop. In other words, designers are able to allow the design to respond to specific input long before a mechanical engineer typically enters the project. The ability to visualize the design, to simulate complex climatic exchanges, and to precisely and cost-effectively fabricate highly customized and finely tuned buildings is the real promise of digital fabrication and what architects and designers have been waiting for.

The industrial revolution offered architects a tradeoff that the Bauhaus embraced: designers could use high-performance materials at high quality and a high level of uniformity, but that required accepting repetition. Today, digital fabrication offers a more compelling proposition: we can achieve all the precision, quality, and performance of industrial systems in multiples of one, offering a uniqueness the equal of something crafted by hand.