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BUILDING INFORMATION MODELING: CURRENT CHALLENGES AND FUTURE DIRECTIONS

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The progression of my career – which has taken me from architecture to manufacturing to the world of software development – has afforded me with a very unusual cross-disciplinary perspective on the evolution of building industry technology. In my early days of working at Hellmuth, Obata + Kassabaum (HOK) and Skidmore, Owings & Merrill (SOM) back in the 1980s, I can remember when computing was just a small outpost within a large professional firm. From HOK, I went on to a company that developed animation software, and I learned much about the form-making programs that have been widely discussed throughout this book. I then entered the arena of manufacturing, working for a mechanical engineering firm that was very much concerned with the connection between product design and the actual process of manufacturing or "machining" those products. It was at this juncture that I was struck by some startling differences between the two industries.

To mechanical engineers, "design intent" referred to a set of very precise dimensions, constraints and parameters that drove the design concept. Their focus was on ensuring that the manufacturers would fabricate the products according to absolutely defined tolerances and specifications – with no ambiguities about what was manufactured.

When I returned to the building industry, I heard a different meaning for "design intent." Architects sought to express their design intent more broadly – clear enough for a contractor to construct the building without explicitly providing directions for how to do so. Why the purposeful ambiguity? According to some, ambiguity is necessary in order to minimize the architect's own liability in case something goes wrong during the construction process. Others say that purposeful ambiguity allows our industry to tap into the distributed intelligence of the community – i.e. that the collective knowledge of how things get built as embodied in designer, builder, manufacturer and tradespeople, is far richer than the knowledge embodied in any one individual or group. Further, limitations on the architect's compensation made finding efficient ways to depict the building necessary.

As we move forward in our discussion of how technology can support the integration of the design and construction process, I think it is important to keep these two distinctive perspectives in mind.

BUSINESS PRACTICE EVOLUTION

A review of a recent AIA Survey (2000–02) yields some interesting insights into how our practice has changed. In the past five years, firm billings have grown by 67%, as opposed to a 14% growth in our economy over the same time period. This means that architectural firms have been making more money recently than they have traditionally earned – so, for some reason, which we need to explore, it has been a heyday for the profession.

Another series of statistics reveals a growing bifurcation in the profession:

- firms with 20 or more employees grew from 5% to 13%
- 40% of all work is in large firms (100 or more employees)
- intradisciplinary work has increased

So, we are finding that the small-size firm – which used to be the mainstay of the profession – is disappearing, while large firms and mid-sized practices are flourishing. But what is most interesting to us as a technology provider is the fact that 90% of all firms use electronic transmissions of digital design information.

DESIGN TECHNOLOGY EVOLUTION

When I first left architectural school in 1980, the state-of-the-art technology was "layered production" – or what we now call manual drafting. Very few firms used computers, or if there was any computer activity at all, it was taking place in the very large firms or "avant-garde" practices. The technology that existed was experimental and expensive – about $100,000 a seat per workstation (hardware and software combined). Few could afford it.

At my job at HOK in the 1980s, I remember that we had retained an employee whose sole responsibility was to schedule use of the "machines." We had many projects going on and had many architects who wanted access to these machines that were extraordinarily expensive relative to human labor costs. So this person's whole day was spent in negotiating with different project managers to make sure they received the appropriate amount of hours to accomplish their tasks on the computers. I remember saying to him one day, "Michael, in three years, your job won't exist. The cost curves are going to cross and we're going to buy enough computers for everybody so we won't need someone to schedule machine time. Instead of people being cheap and machines being expensive, we will have the opposite." He couldn't imagine it. This was about 1985 when the personal computer came on board –

the classic disruptive technology. It was first viewed as a low-power technology that was not taken seriously by mainstream businesses but it quickly gained enough power and promise at a low enough price that it became ubiquitous in firms. By the early 1990s, machines were cheap and people were the expensive resources.

During the 20 years that followed, we refined production-based drafting. And, though, I hate to make predictions, I would say the production drafting problem is largely solved. So where do we go from here?

As we see it, the key to integrating design and construction is through modeling and collaboration. And very closely tied to this next technological evolution is the potential for the architect to reemerge as a master builder – one of the themes of this book.

RESEARCH EVOLUTION

Once again, let me digress into a bit of history, this time within the research community. In the late 1960s and early 1970s, Nicholas Negroponte at MIT was exploring the relationship of the computer to the design process in his book, *The Architecture Machine*, where he identified key stages in this process (accommodation, adoption and evolution). At that time, mainframes were state-of-the-art in computing, and there was a lot of investigation into design methods, to which Bill Mitchell has alluded in Chapter 6. In the 1980s, the focus of research shifted to rendering and visualization, with much of the seminal computer graphics research taking place in that decade. That is when ray-tracing and radiosity were invented, leading to dramatic advances in visualization and a wealth of great imagery. But these techniques did not become mainstream for about another decade.

In the early 1990s, investigations into model-based design first began. In the architectural community, the theoretical underpinnings of "blob" architecture were emerging, while in the computing community work was beginning on pen-based input devices.

Ten years later, we are seeing investigations into four-dimensional computer-aided design (CAD), where the dimension of time is added, as well as collaboration platforms, mobile devices, and the ability to manipulate and display images on very large-scale color screens.

How long will it take for these research advances to become mainstream? By and large, the lag between research and implementation is not for technological reasons but rather for business and economic concerns. How willing are design practices to disrupt their processes and try something new? It will be interesting to see whether the new generation of students that we have talked about will be able to shorten that lag because of their willingness to adopt technology more quickly.

BUILDING INFORMATION MODELING

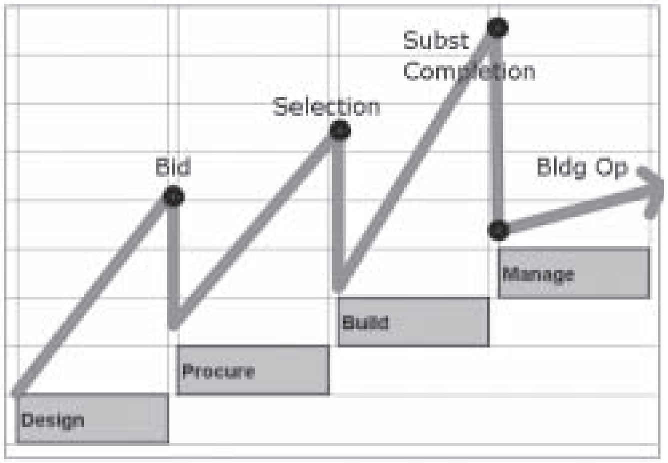
When most people hear the word "modeling," they immediately think of three-dimensional form modeling for rendering and visualization. And while that is certainly an important component of modeling, what we are envisioning is something broader and richer. It is closer to the way the term is used in the manufacturing or mechanical engineering industry – a model that takes into account performance characteristics, cost and other issues related to the construction and operation of a building, as well as its design. A model is not just a three-dimensional picture of geometry, but a rich representation of the building that contains all kinds of interesting and useful data.

To better understand how "modeling" is used in this context, we will examine the building industry process – for we are now exploring how technology can impact the entire building lifecycle, not just the design phase but procuring, building and managing as well.

One might graph the amount of information understood about a building across the phases of design (figure 18.1). In this graph, the horizontal axis is time and the vertical axis is the amount of information that is available about a building project. We start with no information and, over time, we build enormous quantities of information: schematic designs, options and alternatives, sketches, analysis, estimates. Much of the information is in digital format; much remains in the designer's mind. What happens when we go to construct a building in the traditional process? All of that information gets smashed down, plotted out, and printed on dead trees. Turned into paper form, the rich digital design information is lost. As architects, we are afraid of risk and liability, so we do not want to pass all of the information along to the contractor even though some of it may be very important.

So what does the builder do? Well, the builder tries to analyze that information in order to reconstruct the architect's intent. How much is the building going to cost? How should construction be sequenced? From whom should the construction team buy materials and components and subsystems? And if it is a competitive bidding process, then multiple contractors and their multiple sets of subcontractors and suppliers are going through this same process at

18.1.
Creation and loss of information.



the same time. So a tremendous amount of information is being generated to determine how the building is going to get built and how much it is going to cost.

Ultimately, someone is selected for the job. And what happens? You lose a lot of information since the losers in the bidding war toss it all out. Then construction starts and a tremendous amount of information is generated once again. The builder is trying to decipher the architect's design intent, and as the construction team actually tries to construct the building, they find ambiguity in the design. There is a considerable amount of back and forth communication in order to clarify what was originally meant and reconstruct the information. Record drawings may be finally created so that once the building is occupied, the owner does not start from zero but can at least refer to a reasonable set of "as-builts." Of course, these record drawings are often wrong and quickly get out of date.

What is most important here is to realize that we are losing information throughout the entire building industry process. And that is the problem we are to resolve: how to maintain the integrity of information throughout the building lifecycle. Building information modeling, therefore, goes beyond form creation and image generation; it is the creation of digital assets – digital information that is actionable. A paper-based production drawing set does not provide much actionable information in itself; the value of the information lies in a human being's ability to interpret it.

Our challenge is to embed information within the data so that the information is actionable in future phases of the building lifecycle. Building information modeling seeks to fill in the holes, tying in design components with procurement systems and estimating systems. Obviously, both a contractor and building owner are interested in construction costs, and it is very difficult to determine costs from a static two-dimensional drawing. So we are examining ways of actually embedding more information in the design data that can be extracted later on to yield, for example, a more reliable cost estimate.

In my role as a technologist, I often have the opportunity to speak to both architects and contractors, and, as mentioned earlier, the discussion often turns to the issue of "risk." The lens through which they view the world is one of managing risk or being at risk financially. As Jim Glymph said in Chapter 8, in Europe, there seems to be more of a sense of shared risk among building industry professionals than in the United States, where architects operate within a very litigious environment. One approach to this problem is to develop clearer and better building information, closer to the manufacturing engineer's concept of design intent than to the architect's traditionally more ambiguous design expression. As we have just shown, such information could then be used in construction not only for assembling building components but also for such issues as how to best stage construction. The entire construction process is really a design problem in and of itself – and to be able to use digital design information to help resolve these issues would be a tremendous advantage to all.

Of course, a second dimension of risk is compensation. As designers through building information modeling provide more extensive, complete and actionable data to the building enterprise, they should get paid for it. In fact, a model-based approach provides one of the most important opportunities for designers to charge more for their work.

COLLABORATION: THE CONNECTIVE TISSUE

We have been discussing building information modeling and how to create rich, semantic information in a model that goes beyond form to also include function, performance and cost – all of the elements that truly define a real building. To create an environment where design and construction are knitted together, however, a collaboration infrastructure is also needed. Collaboration is a broadly used term these days in technology, and it sometimes occurs in some very mundane and crude ways. We believe, however, that there is a tremendous potential through online collaboration to bring the architect back to the center of the building process and to knit together the various different players in our industry.

Within the design process, the players are usually used to working together within an individual firm with a unified information infrastructure and with work processes that are quite similar. People tend to work with each other in a high bandwidth way; there is a lot of collegiality; a shared vocabulary, language of drawing (in plan, section and elevation) and methodology, and their styles of interaction are clearly defined.

Within the construction process, it is a different story. Typically, the players are a much more loosely knit group. They are often geographically distributed in different places; their relationships may be contentious and adversarial; and they typical use a different type of information technology infrastructure – indeed, multiple types of communication – than the design team, so the solutions for these two groups are often not the same.

But they are both trying to resolve information problems – issues around ambiguity and how to best work together. Even today, collaboration for the most part is handled by printing drawings out on dead trees, marking them up, and shipping them via overnight mailing services. Last year, FedEx made about $500 million on shipping construction drawings around the world. It is a tremendous waste of resources particularly when you can send information digitally.

The current leading-edge technology for project collaboration involves the sharing of project information via project websites. These online project collaboration services are the first wave of collaboration technology solutions and they are helping project teams to efficiently manage data throughout the design and construction of a project. However, they are using today's processes as their paradigm. These services automate the process of moving around documents, but they do not enable the fundamental, deep collaboration that takes places among individuals on a building project team.

As we envision it, this deeper form of collaboration will begin with a design environment in which we have multiple kinds of information: information on the building form and structure, relevant data for construction staging and assembly of building components, product information sheets, and even a job camera to view the construction site. This is how professionals will work – not from the vantage point of a tiny window but by assimilating massive amounts of information in various forms. As professionals, we will add value by making sense of the information and applying it to the particular task at hand.

FUTURE DIRECTIONS AND CURRENT CHALLENGES

We suspect that it will take another 15 to 20 years before building information modeling and collaboration solutions reach the same level of maturity that we have attained with production drafting. So, how can we reach this future? As mentioned, many of the impediments are economic, social and legal concerns that can only partially be resolved by technology. Nevertheless, as technology providers, it is incumbent upon us to address these issues. Our work now is to develop a building information modeling environment and the collaboration tissue that connects these models.

Buildings rarely exist in a static state. They are in a constant process of creation and destruction as people move in and out. They undergo renovation and change and become a part of a larger urban fabric. So, if you examine the building lifecycle, it is not really a linear process at all. Therefore, we have to begin to think about how we can support such a process that has both vertical (spatial) and horizontal (time) dimensions.

The system we envision offers tools for authoring, editing, publishing and analyzing information. In fact, most of the software in use today is really authoring and editing software that is used to create design content or architectural form. We would like to extend those tools so that the architect can publish information that can be extracted for use by others on the team – the estimators, specifiers, construction managers and building owners who need to analyze that information for future activities.

Our current challenge is to provide tools that let building professionals consume information digitally rather than printing it out on paper where it loses its value. Tools that will let us analyze the performance characteristics of buildings (their viability from life safety, structural, mechanical, thermal and acoustical points of view, for example) will result in better coordinated, longer lasting buildings. We are working to provide the ability to analyze a building according to its systems: the site, structure, skin and services. The development of rich building information models with the connective tissue of collaboration techniques and tools will allow us to navigate through this complex building space through time, knitting together design and construction. We are convinced that this process transformation will have a startling side-effect. The architect will reappear on center stage as the master builder of information, the key figure upon which all of the other players in the process depend.