Digital Design and the Age of Building Simulation

Paul Seletsky, Digital Design Director-Skidmore Owings and Merrill **AECbytes Viewpoint #19-**October 31, 2005

We are entering an age of comprehensive, pervasive, digital simulation of the physical world as we know it.

The first manifestation of this digital transformation encompassed matters relative to the gathering of *explicit knowledge*. More simply put: the digital re-presentation of book information; physically tangible, published matter readily found in academic research papers, encyclopedia, maps, dictionaries, etc.; information commonly accepted and disseminated based on documented evidence or experience, adhering to agreed-upon standards and definitions.

The second manifestation—widely recognized and ongoing—encompassed the digitization of network communications, cultural and entertainment media, email and telephone communications, and art, music and film.

The demand for these communications, along with the economic desire for ever-lower production costs, can be seen as having led to yet a third manifestation—the digitization of the manufacturing sector. This encompasses tools developed for and incorporated into the world of mechanical engineering, enabling a resultant computer-driven, robotically mass-produced world of cars, planes, and myriad electronic gadgets; and delivering newly digitized media, along with newly digitally-designed and fabricated products, to an increasingly global audience of listeners, viewers, and consumers.

A fourth manifestation, one enabling advancements in medicine and the physical sciences, was initially achieved utilizing visible waveform technology, followed by more recognizable, graphic, 3D modeling. Used in disseminating exploratory medical findings, this modeling is similar to what architects use today, albeit on a level of far greater geometric complexity and an altogether entirely different scale. The most dramatic advancements, however, have evolved and continue to evolve within the realm of research involving geometric representation of known chemical and physical components, combined with the simulation of those components' respective behavioral patterns (both known as well as potentially unknown). This research synthesizes super-computational number-crunching with *tacit knowledge*—that is, knowledge not readily documented, knowledge based on one's experiences or instincts, more intuitive in nature, and as such more difficult to codify. (For more on this examination of knowledge, see the writings of John Seely Brown, former Director, Xerox PARC). To this author, this type of knowledge extraction can and should be applied to the world of architecture and construction—embodying yet a fifth manifestation. Let us now examine to what extent the significance of such simulation would be.

In the world of architecture, the first instances of digitization occurred with the advent of (CAD) electronic drafting—a progressive step up from manual drafting, certainly, but essentially a substitution of one representational methodology for another. A more significant transformation is now occurring as electronic drafting evolves into what has been commonly referred to as Building Information Modeling (BIM), whereby a model of a building's physical components is constructed digitally, while simultaneously (and inextricably) linked to a report-generating (database) engine, essentially producing what one might call, "smart geometry."

This transformation—one still mostly operative in nature despite BIM's greater visual legibility—will remain incomplete until one begins to see it beyond its current public recognition as a type of enhanced CAD documentation management solution, and over to a more important strategic positioning, one covering a broader range of requirements. The Building Information Model can be the main vehicle of production, or hub, by which a variety of analytical and simulation tools are either applied onto, or directly assimilated into, its "smart geometry," thus transforming the Building Information Model into a predictive disseminator of a building's known (or potentially unknown) behavioral patterns. A virtual embodiment of all accumulated explicit knowledge relative to design and construction methodologies that, combined with the architect's tacit knowledge of design, establishes the correlation that specific designs lend themselves to specific types of building conditions, along with an assortment of associated quantifiable environmental, financial, and performative results (which can also be re-conditioned post factum). Therefore, let us now name this broader vision and call it "Digital Design," defining it hierarchically as follows:

Environment of Digital Design

Vision	**Description**
Conceptual Model	Building Requirements: 'Blocking & Stacking'
Building Information Model	Geometry Development / Data Production Hub
Visualization Model	Presentations / Renderings / Animations
Analysis and Simulation	Environmental Prediction and Behavior
Enabled Design	Applied Knowledge, Building Codes, Specs
Documentation	2D Drawing 'Extraction' from BIM Model
Building Information Model 'As Built'	Construction Sequencing & Management
Building to Model Feedback	Live Environmental Report (Building to BIM)
Model to Building Feedback	Live Environmental Change (BIM to Building)
Robotic Construction	"Architecture is a Machine for Living in"

New computationally-driven simulation methodologies being developed both within academia and commercially, can (and will) virtually simulate everything from basic lighting, energy, wind, and pedestrian circulation conditions to more advanced construction, fabrication, code, material, and security conditions. Easily misunderstood as supplemental engineering data—the mundane, statistical information, commonly applied after-the-fact to design projects—the new Digital Design argues that digital building simulation will embody the future of architectural practice; that those practitioners seeking a wider role beyond that of form-giver will be significantly empowered by the use of tools generating such analytical information, applied before- and after-the-fact, from the project's conception, into its design and construction phases, and then well beyond, into its occupancy and lifecycle management stages. Properly understood and utilized by the profession, this entails a significant rise in the architect's stature, as the advantages of informed, rather than speculative, decision-making become self-evident. Properly ignored, the results may very well promote Construction Managers into a lead decision-making role, whereby architectural design is subsumed as a service within the construction firm. And in instances where more recognizable architectural talent is desired, it can be readily licensed." Witness the session description to an upcoming building technology conference:

"*There is a new professional title percolating up through the ranks in construction—the 'construction modeler.' This new breed of construction professional is creating 3D models—with or without input from the architect—specifically for construction purposes. Come explore how these new professionals are using 3D models for constructability analysis, better estimates, sequencing and procurement optimization, and increased data flow to fabrication*."

The very use of Building Information Modeling implies a radical re-thinking of the design process itself, and the deliverables typically associated as being produced by architects, either as individual practitioners or within firms. Reviewing new BIM tools in the mainstream architectural press and even attending recent industry gatherings on BIM, one observes scant discussion paid to the tremendous cultural shift that must necessarily occur as architectural design teams adopt the technology and begin producing digital building components, then start assembling those components into digital buildings, much as one would physically assemble and construct a building in actuality. This is a complete cultural and procedural shift from the process of producing CAD drawings that few seem to understand, one analogous to participating in the creation and assembly of a large-scale, complex, 3D jigsaw puzzle in which all the players' pieces must fit together exactly—or not be used at all.

The significance of this cannot be underestimated and should be repeated—the current architectural production methodology (and all associated deliverables) is about to be completely turned on its head. Architects (and newly hired design school graduates) will now have to think in terms of producing and assembling building components, as opposed to sheets of drawings or seductive renderings; they will have to shift their thought processes away from one of representational geometry to one of component objects, their assembly, and an understanding of actual construction and fabrication.

Furthermore, architects will now have to adjust their understanding of collaboration as one occurring synchronously (in real time) within a team creating and assembling an interrelated set of building components, versus occurring asynchronously (at staggered times) with a team creating and assembling a loosely interrelated set of drawings. Now digital components will be saved back to a central building model, with confirmation immediate as to their integration, versus CAD drawings stacked in a pile or folder; loosely aligned relative to line weights, layers, sections, and details, and 'fudged' when things don't quite line up. There will be complete propagation of BIM design changes versus painstakingly laborious manual CAD changes.

This is a radically different notion of collaboration as understood and commonly played out in professional practice and academia (see Figures 1 and 2). Confusion and common mislabeling as to what constitutes Digital Design, for example, can be found equally in both camps. This is to be expected, especially given centuries of architectural culture exalting the individual as a lone, supreme, inventor of form; the means of production defined as an assembly of representational drawings produced by individuals working in tandem.

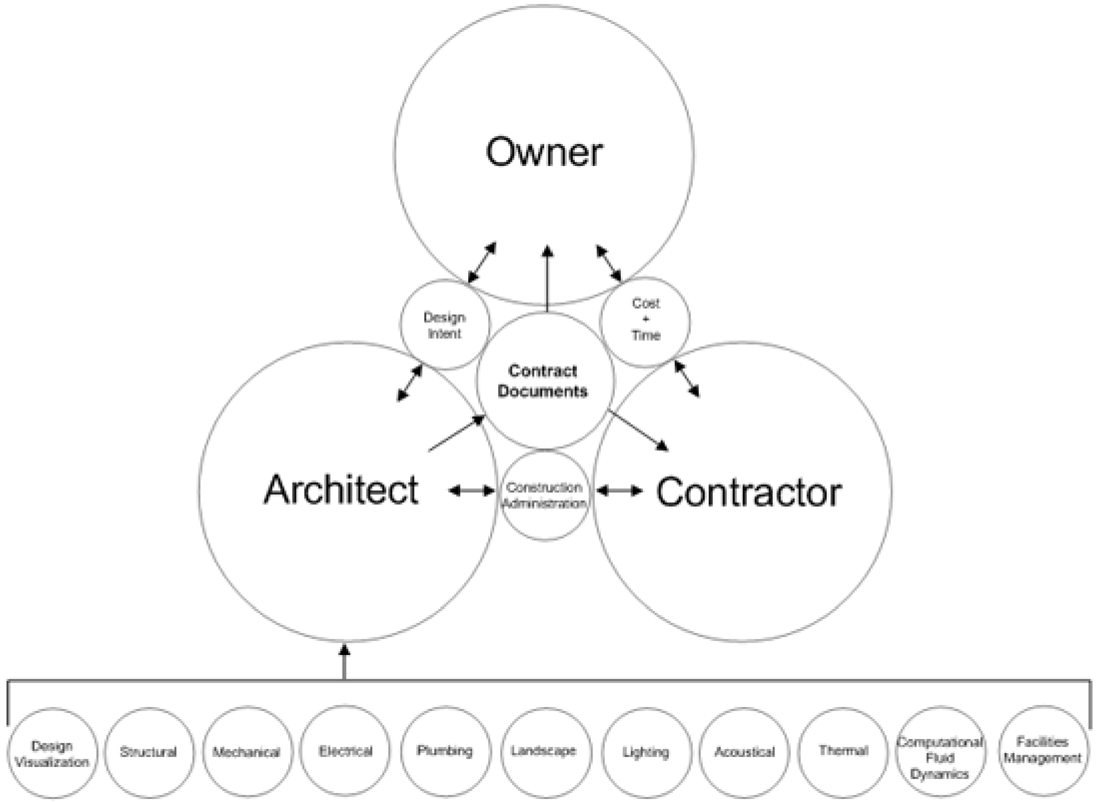

Figure 1: CAD: Design + Documentation + Communication

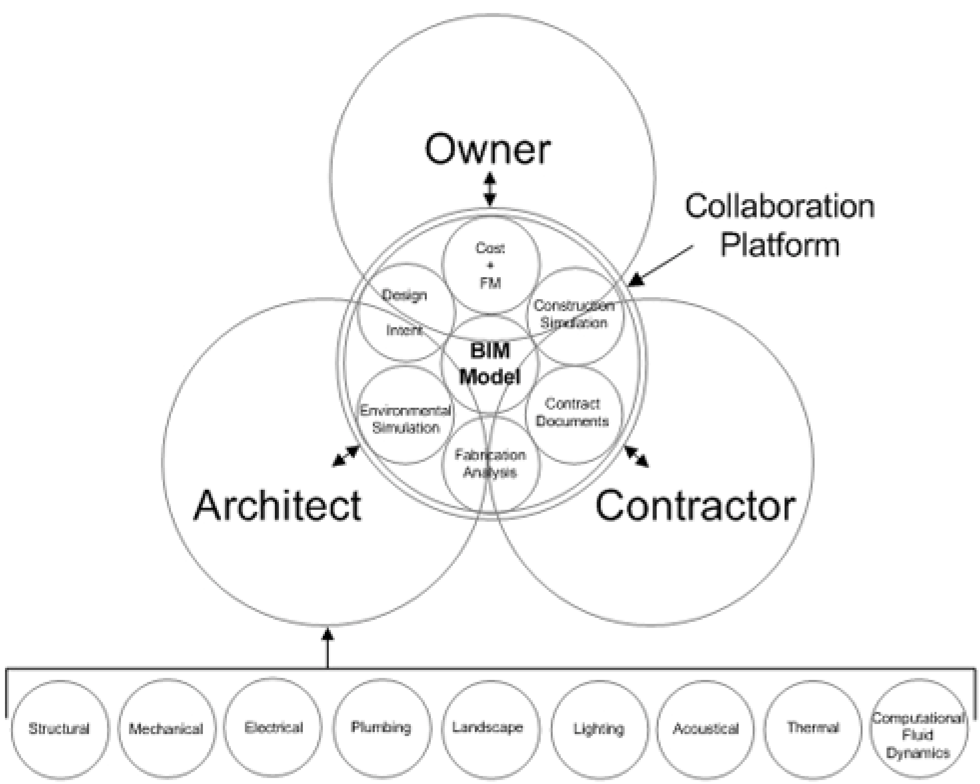

Figure 2: Digital Design: Model + Analysis + Simulation + Communication

This then begs the question, "Does the use of simulation and analysis as applied within the context of Digital Design suggest that artistic license or one's inherent creativity must now fall by the wayside?" Quite the contrary: One could reasonably argue that any new architectural design—however esoteric in nature or capricious in appearance—produced using these tools could now be validated, held accountable, be justified by the resultant quantitative analysis data engendered. Rephrased: Architects will now be able to present quantifiable, environmental and engineering data as an inherent, essential part of their design rationale, or partí. This information will be displayed simultaneously from one central source, as opposed to a collection of reports provided by a variety of specialists over a given period of time. All imaginable conditions would be on display and seen within a singular environment, allowing their relationships and inter-relationships to be thoroughly examined. Nothing would be left to chance.

A century-and-a-half back in time, it was not uncommon for doctors to be referred to as "quacks," their methodologies frequently based on speculative guesswork, unaccompanied by any scientific research or analytical data to back up their ideas. Indeed, medical science did not evolve (and the medical profession did not get taken seriously) until academia, fending off great public disdain and apprehension, began to study the human body in actuality and transpose those observations into illustrative drawings, then into operative diagrams. This, in order to better understand the relationship of the body's various components relative to its structural and circulatory systems. One would not go to a doctor today without possessing the subconscious knowledge that the practitioner is well-versed in codified knowledge—received through an accredited medical school—and is not someone running a practice based on "gut instincts," or "an intuitive search for new languages in medicine."

In the design and introduction of any new car today, we take for granted that the car possesses a modicum of logical, environmental, and functional engineering, and is not just "thought out" but its components and conditions are thoroughly "computer-designed." Its features are formulated, analyzed, and simulated. Moreover, we expect that the car's interior shell, while perhaps not possessing the most luxurious of materials available, will at least enjoy the proper amount of heating and cooling conditions, fresh air circulation, noise reduction; that its windshield glass will reduce glare and not shatter; that it's dashboard controls will accurately register and report the proper amounts of fuel, security, and safety conditions; that there will be an owner's manual in the glove compartment for future reference to replacement parts and long-term care; and that there will be a mileage estimate sticker at the dealership, so that one can determine beforehand how much the car will cost to operate. Indeed, we no longer demand that new cars possess these conditions and that all known possible functions and malfunctions be understood and addressed through simulation before purchase or occupancy. We unequivocally expect that flawless engineering will be an integral part of every new car—from design through delivery.

All arguments comparing life-safety, mass-production, and economies-of scale aside: if we expect our medical professionals to perform their duties properly, have their professional credentials validated through successful implementation of well-researched and well-documented procedures; if we expect that automobiles will successfully meet the extensive performance and environmental criteria required of them, *before going into production*; and if we understand that both of these sets of expectations are being successfully met through the incorporation of knowledge-driven research, analysis, and digital simulation tools, should we not then expect the same from our architects and our buildings? Indeed, we should expect them to live up to the same high standards, employ the same advanced technologies, utilize the same simulation and analysis methodologies, and incorporate the same tacit and explicit knowledge into publicly-accepted, digitized, procedural methodologies as would be expected from any other profession. Their expertise on the built environment should then, in turn, be more widely recognized and respected.

As we move forward it will become clearer that the incorporation of knowledge-driven analysis and digital simulation tools into the architect's world will not only validate their design intent but, in so doing, validate their role as one singularly understanding of the direct linkage between design intent and building performance. This will also provide their clients with access to construction costs, environmental considerations, and a harbinger of long-term maintenance costs (before they occur), at a level of immediacy and detail they simply have not had access to before. It would not be unreasonable for an owner to expect a digital "owner's manual," as with new cars, when occupying a new home, office tower, or hospital—a Building Information Model encompassing more than just geometric considerations, loaded with all manufacturers' component serial numbers, their unit costs, and perhaps online ordering capabilities. It is highly unlikely that consumers would accept the idea of purchasing an automobile whose costs had increased 25% upon travel from the assembly line to the dealership. Building clients should not have to endure the same.

If these comparisons and questions seem simplistic and their arguments dismissed outright, then one might ask to what purpose, exactly, does technology serve architects and their clients? The Digital Design tools now entering the market perhaps seem primitive (as hopefully they will in time) but they are just starting to provide motivated professionals with the ability to study, observe, analyze, formulate, automate, simulate, and derive predictive, results-oriented decisions and benefits. These benefits do not have to be limited to architects' and engineers' means of production alone. In an age dominated by skyrocketing health insurance and malpractice premiums, consumed by homeland security, it would make sense for the insurance carriers to require or create incentives for large firms to have quality assurance procedures in place that include the use of Building Information Modeling. They would encourage the predictive benefits offered by Digital Design, the opportunities for safer construction sites, improved indoor environmental health, quicker emergency evacuation procedures, and increased building security, all viewed centrally via the Building Information Model.

Architects employing Digital Design would also be able to offer their clients—and themselves—better opportunities in their compensation and fee structures, as billings would no longer be based on calculating (CAD) labor over time but a (BIM) deliverable supplied en masse. Clients could opt for a larger lump sum fee payment up front, in return for an overall lower cost. (Imagine, architects no longer waiting to receive payment on their final billings!). The Building Information Model's delivery mechanism and its ability to govern, regulate and modify the environmental conditions of the physical building it is simulating will raise issues as to ownership rights and ongoing facilities management services. This, too, will present opportunities for architects and their clients to sustain ongoing relationships beyond physical completion of their projects, and provide revenue for architects to underwrite their business operations when work opportunities become lean. It will become possible to deliver simulations as "electronic deliverables," for example, energy/daylight simulations for energy code compliance and the CORENET simulations developed in Singapore for local building code compliance. (See the recent AECbytes feature on the CORENET project.)

The movement toward digital building simulation will re-instill the understanding that architects indeed play a vital, central, and pivotal role in the design and construction processes; that enabling the virtual embodiment of their tacit and explicit knowledge into codified, digitized, simulated and predictive behavior carries with it certain responsibilities demanding their forthright attention and should also, therefore, confer their leadership status on the process. These are responsibilities that have, over the last century or more, been progressively shunned or legislatively whittled away due to liability concerns. It will require that the various professional architectural associations and institutional bodies—who claim to be in touch with the future—re-examine contractual agreements written over a century ago. It will require these associations to seize the day, and take a more proactive stance on legislating architects' ownership of the Digital Design process, as a right of the profession; to cease all inane chattering while others take on the responsibilities—and enjoy the benefits—of Digital Design. The focus must go beyond providing contractual documents online, discussions of unenforceable national BIM standards and data exchanges, and toward legislative assurances that architects will govern and lead the Digital Design process, much as medical professionals govern their destiny. A good place to begin would be in fostering a national educational campaign—for architects and the public—as to the advantages that architects possess in using Digital Design. A second important step would be in the creation of a certification program engendering the sustained implementation of Digital Design into professional practice, recognizing those individuals and firms actively using the current crop of Building Information Modeling tools, in much the way LEED certification has fostered greater participation in green building design. A third step would be for these organizations to financially endow the National Science Foundation and other government underwriting research bodies, enabling them to pursue ongoing research and development which advances analysis and simulation tools specifically geared for architects. These initiatives must then lead to a revitalized, more meaningful, licensure (and licensure maintenance) process.

The movement toward digital building simulation will also require that the current educational process be re-evaluated and re-engineered, and begin to address not only the development of the individual student's design talents but his or her ability to engage in new collaborative methodologies heretofore unaddressed, let alone understood. A need to understand and employ these new methodologies will arise regardless of whether the student pursues an individual path of practice or within a firm. Thus, the recommendation is that a dual curriculum core, one encompassing design and theory as well as one focused on collaborative project means and methods, should be developed. Exploring new forms relative to syntax will always be important but so will an understanding that architectural projects do not just begin and end with architects; that any given project environment extends to a larger collaborative core team comprised of structural, systems, and construction management engineers. The ability to suitably integrate their BIM models into one cohesive model governs the very heart of what Digital Design, analysis, and simulation is all about. As the production methodology shifts away from representational drawing to one of component modeling and assembly, architecture students need to possess, at minimum, an ability to comprehend materials assemblies, integration of BIM structural and MEP systems (with particular emphasis on conflict detection), fundamentals of project staging and site logistics, impact of weather conditions, and so on. Much as pilots are now trained to fly using flight simulators, architecture and engineering students must now begin to do the same; and they must train to work interactively with one another, much as they would do in actual professional practice.

Deans of architecture schools should embrace, rather than withhold, opportunities to give their students greater flexibility in developing their talent and skills: Digital Design will not lead to muddying the creative waters, or a vocational bent, any more than acquiring new techniques or applying new ideas has ever stifled creativity or imagination. Architecture students need also explore a variety of programming languages to hone their ideas, as opposed to relying only on commercially-available software tools. This should be followed by exposure to new rapid-prototyping equipment, thereby familiarizing students with enhanced fabrication methodologies and the opportunities they afford.

An awareness of programming and its complexities should also the lead the profession to re-examine its posture on the ability of the commercial software industry to provide architects with the Digital Design tools they believe they need. Architects must begin to abandon unrealistic expectations by offering these developers, instead, a sustained financial framework (guaranteeing revenue and seat commitments) that will target development of specific digital tools with financial reward, delivering new tools to organized firms or consortia based on specific requests. This is common practice in almost every other commercial industry, except for architecture! The predominant wait-and-see attitude, deriding software programs that must necessarily address as broad a market sector as possible (and thereby cater to the lowest common denominator), stifles creativity and satisfies no one.

Finally, the incorporation of Digital Design into the world of architecture will help establish the principle, once-and-for-all, that it is not enough to "*just design*," or "*just construct*"—just as it is not enough to "just perform surgery." Perhaps it is not a matter of life and death, but if architecture is the blending of science and art, how much more rewarding and satisfying it will be for architects to finally be able to conceive and develop their ideas—however far-fetched or esoteric—and then explain their motives not only through artistic treatise or philosophical, mathematical, or linguistic manifesto but with building simulation data that irrefutably validates design intent, performance conditions, and all other areas of concern; that they have all been put into action and are known to work; that the building is not only stimulating visually but actually "performs well," as witnessed through all its digital simulation modes leading to digital fabrication and construction. No sound architect should dismiss the opportunity to implement a more legible dissemination tool into the construction process if it guaranteed that their designs would no longer be inadvertently altered or cheapened at the last minute, and that it not only led to a significant improvement in the realization of their work but also enhanced the value and stature by which their clients view them. The ability to take advantage of this new technology can only come from those who are (and will become) fluent, conversant, knowledgeable, and certified in the use of Digital Design, its tools and methodologies and integration into the practice of architecture.

The age of Digital Design and digital building simulation is now upon us. It is more than just the introduction of a new set of computer tools that architects can use to better coordinate their construction documents. It belies the future of the architectural profession itself.

About the Author

Paul Seletsky, Associate AIA, is the recently appointed Director of Digital Design for Skidmore Owings and Merrill's New York office. In this role he coordinates the strategic implementation of technology as defined by Digital Design, encompassing greater understanding and utilization of Building Information Modeling as well as building the cultural foundations necessary for such change. His goal is to foster discussion on a variety of advanced software and hardware topics, leading to greater adoption of these design tools and their processes. A 1982 graduate of the Irwin S. Chanin School of Architecture at the Cooper Union for the Advancement of Science and Art in New York, he is also the chair of the AIA NY Chapter's Technology Committee, and a member of the AIA's Technology in Architectural Practice (TAP) Committee. He has been managing technology in both its operational as well as strategic capacities for the last sixteen years. He can be reached at Paul.Seletsky@som.com.

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