

DIGITAL AGE ARCHITECTS: INFORMATION MASTER BUILDERS?

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NOTE

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ABSTRACT

The digital age is providing unprecedented opportunities for the significant redefinition of the architect’s role in the production of buildings. Digital technologies are enabling a direct correlation between what can be designed and what can be built, thus bringing to the forefront the issue of the significance of *information*, i.e. the issues of production, communication, application, and control of information in the building industry. By integrating design, analysis, manufacture, and the assembly of buildings around digital technologies, architects, engineers and builders have an opportunity to fundamentally redefine the relationships between conception and production. The currently separate professional realms of architecture, engineering, and construction can be integrated into a relatively seamless digital collaborative enterprise, in which architects could play a central role as *information master builders*, the twenty-first century version of the architects’ medieval predecessors.

INTRODUCTION

One of the most profound aspects of contemporary architecture is not the rediscovery of complex curving forms, but the newfound ability to generate *construction information* directly from *design information* through the new processes and techniques of digital design and production. It was the complexity of “blobby” forms that drew architects, out of sheer necessity, back into being closely involved with the production of buildings. The continuous, highly curvilinear surfaces, which feature prominently in contemporary architecture, brought to the fore the question of how to work out the spatial and tectonic ramifications of such complex forms.

The challenges of constructability left designers of new formal complexities with little choice but to become closely engaged in fabrication and construction, if they were to see their projects realized. But as constructibility becomes a direct function of computability, the question is no longer whether a particular form is buildable, but what new instruments of practice are needed to take advantage of the opportunities opened up by the digital modes of production. Building contractors, used to the current “analog” norms of practice and prevalent orthogonal geometries, were reluctant to take on projects they saw as apparently unbuildable or, at best, with unmanageable complexities. The “experimental”

architects had to find contractors and fabricators capable of digitally-driven production, who were often not in building but in shipbuilding. They had to provide, and often generate directly, the digital information needed to manufacture and construct the buildings. So, out of sheer necessity, the designers of the digitally-generated “blobby” architecture became closely involved in the digital making of buildings.

In the process, these architects discovered they have the digital information that could be used in fabrication and construction to directly drive the computer-controlled machinery, making the time-consuming and error-prone production of drawings unnecessary. In addition, the introduction and integration of digital fabrication into the design of buildings enabled architects to almost instantaneously produce scale models of their designs using processes and techniques identical to those used in the industry. Thus, a valuable feedback mechanism between conception and production was established.

This newfound ability to generate construction information directly from design information, and not the complex curving forms, is what defines the most profound aspect of much of the contemporary architecture. The close relationship that once existed between architecture and construction (what was once the very nature of architectural practice) could potentially reemerge as an unintended but fortunate outcome of the new digital processes of production. In the future, being an architect will also mean being a builder, not literally, of course, but by digitally generating the information to manufacture and construct buildings in ways that render present inefficient hierarchies of intermediation unnecessary.

The new processes of design and production, born out of the pragmatic ramifications of new formal complexities, are providing unprecedented opportunities for architects to regain the authority they once had over the building process, not only in design, but also in construction. The new relationships between the design and the built work place more control, and, therefore, more responsibility and more power, into the hands of architects.

By integrating the design, analysis, manufacture and assembly of buildings around digital technologies, architects, engineers and builders have an opportunity to fundamentally redefine the relationships between conception and production. By reinventing the role of a “master builder,” the currently separate disciplines of architecture, engineering and construction can be integrated into a relatively seamless digital collaborative enterprise, thus bridging “the gap between designing and producing that opened up when designers began to make drawings,” as observed by Mitchell and McCullough¹.

HISTORY OF DISASSOCIATION

For centuries, being an architect also meant being a builder. Architects were not only the masters of spatial effects, but were also closely involved in the construction of buildings. The knowledge of building techniques was implicit in architectural production; inventing the building’s form implied inventing its means of construction, and vice versa. The design information was the construction information – one implied the other.

The master builders, from the Greek *tekton* (builder), to the master masons of the Middle Ages were in charge of all aspects of buildings, from their form to the production techniques used in their construction. They had the central, most powerful position in the production of buildings, stemming from their mastery of the material (stone in most cases) and its means of production. As the palette of materials broadened and the construction techniques became more elaborate, the medieval master masons evolved into master builders (or architects) who would integrate increasingly multiplying trades into an increasingly more complex production process.

The tradition of master builders, however, did not survive the cultural, societal and economic shifts of the Renaissance. Leon Battista Alberti wrote that architecture was separate from construction, differentiating architects and artists from master builders and craftsmen by their superior intellectual training. The theory was to provide the essence of architecture, and not the practical knowledge of construction.

Paradoxically, the history of architecture's disassociation from building started in the late Renaissance with one of its most celebrated inventions – the use of perspective representation and orthographic drawings as a medium of communicating the information about buildings. The medieval master builder (architect) used very few models and drawings to test or communicate ideas, and relied instead on direct verbal communication with craftsmen, which, in turn, required continuous presence on site, but provided for a seamless exchange of information at all phases of building. With Alberti's elevation of architects over master builders came the need to externalize information (so it could be communicated to tradesmen) and the introduction of orthographic abstractions, such as plan, section and elevation, into the currency of building. Architects no longer had to be present on site to supervise the construction of the buildings they designed.

The rifts between architecture and construction started to widen dramatically in the mid-nineteenth century when “drawings” of the earlier period became “contract documents.” Other critical developments occurred, such as the appearance of a general contractor and a professional engineer (first in England), which were particularly significant for the development of architectural practice as we know it today. The relationships between architects and other parties in the building process became defined contractually, with the aim of clearly articulating the responsibilities and potential liabilities. The consequences were profound. The relationship between an architect (as a designer of a building) and a general contractor (as an executor of the design) became solely financial, leading to what was to become, and remain to this day, an adversarial, highly legalistic and rigidly codified process. It is the biggest obstacle to change today.

The late-nineteenth century New York firm McKim, Mead and White is often cited as another example of the power architects once had over the building process. As described by Howard Davis,² this architectural firm, in its quest for total control over the construction of each of their buildings, produced not only hundreds of drawings, but also had a final say over every detail, the quality of materials and workmanship, and over every payment to contractors and subcontractors. But this high degree of control was not without consequences. As architects placed more and more layers beneath themselves,

the distance between them and the construction site increased. As Davis observes, “As the system evolved further, the role of the general contractor grew at the same time as the architect’s connection to craftspeople lessened.”³ Although architects were at the apex of hierarchical control structure, increasingly the desired outcome had to be explicitly and precisely described in various “contract documents.” The architect’s role on the construction site, instead of shaping the building (as master builders once did), became the contractual administration, i.e. the verification of the contractor’s compliance with the given contractual construction documents. The design was split from the construction, conceptually and legally. Architects detached themselves fully from the act of building, unintentionally giving up the power they once had, pushing the design to a sideline, and setting the profession on a path of increasing irrelevance in the twentieth century.

The twentieth century brought the increasing complexity to building design and construction, as numerous new materials, technologies and processes were invented. With increased complexity came increased specialization, and the emergence of various design and engineering consultants for different building systems, code compliance, etc. At the same time, the amount of time allotted for design and construction was shrinking. As the complexity of building increased and the design “time” decreased, the architects sought the need to limit their liability exposure. While the legal definition of their role was becoming progressively more defined, architects were, at the same time, increasingly losing control and the decision-making power over the building process, thereby formally dissolving the authority they once had and knowingly disassociating themselves from the rest of the building industry.

In the United States today, architects are prohibited from taking part in construction by the codes of practice established by the professional association, the American Institute of Architects (AIA). The standard contracts in use by the AIA state explicitly that “the architect will not have control over or charge of and will not be responsible for construction means, methods, techniques, sequences, or procedures.”⁴ This aversion to risk has, unsurprisingly, led to the further marginalization of architectural design, further contraction in services offered by the design firms, and further reduction in fees.

The outcome of this progressive disassociation of architecture from the rest of the building industry is a profession unsure of its role in contemporary society and its economy, and a profession unable to respond to the challenges and opportunities of the Information Age. Only by taking the lead in the inevitable digitally-driven restructuring of the building industry will architects avoid becoming irrelevant.

THE DIGITAL CONTINUUM

It is debatable whether the drawings emerged in the building industry because of the need to separate design and construction, or whether their introduction produced the present separation. The lasting legacy is the legal framework within which building industry professionals operate today, requiring drawings, often tens of thousands of them, for a project of medium size and complexity. Only the present divisions of responsibility make this production of drawings necessary. In other industries, such as shipbuilding, the

designer and the builder are often one legal entity, so there is little or no need to produce drawings, i.e. to externalize design information. Many shipyards and boatyards have eliminated drawings by working directly with a comprehensive three-dimensional digital model from design to construction. The digital geometric data extracted from the model are used to directly drive the automated fabrication and assembly equipment.

Fortunately, the digital revolution that radically restructured the shipbuilding and other industries did not go unnoticed in architecture. Some architects were quick to exploit the design and construction opportunities that were opened up by the newfound ability to digitally generate and supply the manufacturing information to fabricators and contractors, and, in turn, their ability to reciprocate by providing accurate material and cost estimates. In these newly discovered mutually-beneficial processes of direct information exchange, the digital design information became the construction information, and vice versa, without the intermediate time-consuming and error-prone steps of drawing production. These digital processes, pioneered by Frank Gehry's office, represent a radical departure from the normative practices – they eliminate, rather than automate, the production of various construction documents as paper drawings. The digital data are passed on directly, i.e. in paperless fashion, to fabricators for cost estimation and fabrication.

The ability to digitally generate and analyze the design information, and then use it to directly manufacture and construct buildings, fundamentally redefines the relationships between conception and production – it provides for an informational continuum from design to construction. New synergies in architecture, engineering and construction start to emerge because of the use of digital technologies across the boundaries of various professions. As communication among various parties increasingly involves the direct digital exchange of information, the legacy of the twentieth century in the form of drawing sets, shop drawings and specifications, will be inevitably relegated to the dustbin of history. The need to externalize representations of design, i.e. produce drawings, will lessen as a direct consequence of the new digital possibilities for producing and processing information.

As production of the drawings declines, i.e. as digital data are increasingly passed directly from an architect to an engineer or a fabricator, and vice versa, so will the building design and construction processes become more efficient. By some estimates, there is a potential for building construction to become 28–40% more efficient through better (digital) information and coordination.⁵ But for that process to begin, the legal framework of the building industry, in which the drawings establish the grounds of liability, would have to change. In other words, the nineteenth century building practices would have to change for architects to work directly with fabricators, i.e. subcontractors. This “disintermediation”⁶ should bring new efficiencies. According to James Cramer, Chairman and CEO of Greenway Consulting, architects will find themselves “moving from linear to non-linear changes – from information that is shared by teams, rather than individuals, and communication that is continuous, rather than formal and fragmented.”⁷

In this scenario, the digital model becomes the single source of design and production information that is generated, controlled and managed by the designer. It encodes all the information needed to manufacture and construct the building. Layers of information are added, abstracted and extracted as needed throughout the design and construction, as architects, engineers, contractors and fabricators work in a collaborative fashion using a single digital model from the earliest stages of design.

Such a model of production requires that all tools for design, analysis, simulation, fabrication and construction be integrated into a single, cohesive digital environment that can provide information about any qualitative or quantitative aspect of building under design or construction. The challenge is (and has been for more than three decades of computer-aided design) how to develop an information model that facilitates all stages of building, from conceptual design to construction (and beyond, for facilities management), and provides for a seamless digital collaborative environment among all parties in the building process.

By digitally producing, communicating and controlling the information exchanged between numerous parties in the building process, architects have an opportunity to place themselves in a central, key role in the construction of buildings and perhaps even regain the absolute powers of the medieval master builders. The four-dimensional digital model of a building as a single source of information would enable the architects to become the *coordinators (master builders) of information* among various professions and trades involved in the production of buildings. Whether they want to do that is a complex issue, as there are numerous social, legal and technical barriers to the complete restructuring of long-ago established relationships among the various building professions and trades.

For Gehry's office, a digital model created in CATIA (Computer Aided Three-dimensional Interactive Application) – the design and manufacturing software used mainly in the aerospace industry – is the single source of design and construction information (figure 1). In a remarkable departure from the current norms of practice, the three-dimensional digital model is actually a key part of the contract documents, from which all dimensional information is to be extracted during the fabrication and construction of the building. In other words, the digital model takes precedence over any other construction document, legally and in practice, on the construction site. This is a radical, revolutionary change in building practice, for which Gehry's office will probably be remembered in future history books (and not only for the sinuous, curving geometries of the *Guggenheim Museum* in Bilbao, Spain).

The single, unified digital model, as envisioned by James Glymph, one of Gehry's partners, places the architect in the role of a “coordinator of information”⁸ between the various participants in the design and construction of a building. The principal idea is to unify, i.e. to bring together in a single digital information environment, the hundreds of different parties involved in a typical building production, with the aim of overcoming the inefficiencies, resource-wise and information-wise, that result from the conventional divisions of responsibility and modes of production in the various professions.

Gehry's office first experimented with the "paperless" process of digital production in the late 1980s in the design and construction of the large fish-shaped pavilion at the entrance of a retail complex on Barcelona's waterfront (1992, figure 2). It was a watershed project for the office. As was the case with all of Gehry's projects later on, a physical design model was generated first and was then translated into a corresponding digital surface model. The digital model was further refined; the wireframe model was extracted and used by structural engineers to develop the supporting structural frame. A physical scale model was machined from the digital version for comparison with the initial conceptual model. The digital model was then used in the full-scale construction to directly control the production and assembly of the components. For the first time, the construction drawings were not needed to erect the building. This process of project development and production, with some variations, was used by Gehry's office on a number of projects. Particularly notable among recent projects are the *Experience Music Project* (2000) in Seattle and the *Walt Disney Concert Hall* (2003) in Los Angeles, whose design and construction represents the most complete use of digital technology by Gehry's office so far.

According to Gehry, particularly appealing is the newfound ability "to get closer to the craft"⁹ by engaging the digital technology directly in the production and thus eliminating the many layers that exist between the architect and the act of building. To Gehry, that means one thing – "it's the old image of the architect as master builder," who now has control over the building process from beginning to end. Thus, the basic idea of the Bauhaus (of the unity of the craftsman and the artist) from the early twentieth century is re-actualized at the beginning of the twenty-first century.

CHALLENGES

In the new digitally-driven processes of production, design and construction are no longer separate realms but are, instead, fluidly amalgamated. Builders and fabricators become involved in the earliest phases of design, and architects actively participate in all phases of construction. The fission of the past is giving way to the digital fusion.

This model of a digitally-facilitated collaborative continuum from design to construction, while opening up unprecedented opportunities for the building industry, faces a number of difficult, multifaceted challenges, which must be overcome for this new digital continuum to become a reality. The principal obstacles stem from the long-established social and legal practices in the industry. Its highly fragmented and differentiated structure, which, while facilitating a clear definition of the responsibilities, does stand in the way of new collaborative synergies emerging in the industry.

The sharing of digital data among various parties in the building process is, in fact, discouraged by the current legal codes of practice. Under the current definitions of professional liability, if an architect transmits a digital model or a drawing to a contractor or a fabricator, he or she becomes liable for any work resulting from the given digital data. The consequence is that each participating party in design and construction creates its digital data from scratch, i.e. from paper documents reproduced from the previously

digitally-generated information. Needless to say, this process is not only highly redundant and utterly inefficient, but it also compounds any errors that could occur in interpreting the information exchanged on paper.

While uniting all the participants through a single modeling system, as discussed earlier, does hold a promise of a remedy for the present redundancies and inefficiencies, it makes the responsibilities of different parties far less distinct than is presently the case. If the building industry were to adopt this new *modus operandi* of shared responsibilities, it needs to clearly assess the legal repercussions and embark on a fundamental redefinition of relationships among various parties in the building industry, with the help of legal and insurance experts. A radical restructuring of the industry, while technologically possible today, is an enormously difficult task because of the tremendous social and cultural inertia of the firmly entrenched traditions, developed slowly over several centuries.

The transition is then likely to be evolutionary rather than revolutionary. Gehry's office, for example, relied on a "hybrid" system in which an owner-contracted consulting firm (called *C-cubed*, and led by Rick Smith) provided digital modeling services in CATIA to all members of the design and construction team, effectively coordinating the production of the shared digital model. Each team member extracted and added information to the shared model as mandated by their expertise without crossing the traditional lines of responsibility and thus staying within the limits of liability established by the legal and insurance rules. Had Gehry's office assumed the responsibility for the development and data coordination of the digital model, they could have been liable legally as a professional architectural firm for the information provided by other members of the team.

While this solution protects the architect and creates an elegant legal "umbrella" for the rest of the design and construction team under the existing rules, it places significant responsibility on the owner-contracted consulting firm as a "data manager." This is an emerging role that needs a full and clear definition as challenges of accurate and integrative production of information become more and more demanding. It is this role – the building information manager (I prefer information master builder) – that represents the greatest opportunity for architects to return to their master-builder roots. The architectural profession will seal its fate if it abandons the overall process and information integration and management to construction and engineering firms, some of which have already realized that the emerging dynamic, geographically distributed, digital networks of design and production expertise are the future mode of operation for the building industry.

With greater responsibility comes increased liability, i.e. a greater assumption of risk, but also greater rewards. According to James Glymph, "both money and time can be eliminated from the construction process by shifting the design responsibility forward."¹⁰ Glymph offers, as an example, the cost of producing the shop drawings, which far exceeds the architectural and engineering fees for a typical large-scale project. But if architects were to provide the information for the benefit of other members of the design and construction team, they ought to be compensated for that new role. The restructuring

of the industry therefore requires not only professional and organizational adjustments, but also a rethinking of how various members of the team are compensated.

In the *Stata Center for Computer, Information, and Intelligence Sciences* (2003) at MIT, Gehry's office is breaking new ground by sharing the overall responsibility for the project with other members of the building team. The concept of shared liability is a remarkable departure from the current distributed liability of building practice. It is, perhaps, the most difficult challenge to overcome, as it represents a complete reversal of the present position by architectural professional organizations and insurance companies of minimizing the liability of architects in the building process. If they were to remain relevant as a profession, architects will have to learn to share responsibility with other members of the building team, as they once did.

Some architects have responded to the opportunities and challenges that come with shared responsibility by teaming up with contractors to create *design-build* firms, which serve as both architect and contractor to the owner, thus representing a single legal entity and a single point of responsibility. This change in the structure of building practices, and the resultant redefined legal framework that provides for shared decision-making, is one possible logical remedy for the present inefficiencies of a highly fragmented building industry. By some estimates, one-quarter of all construction projects in England and one-tenth in the United States are now done as design-build.¹¹

Design-build, however, is only one way of actualizing the emerging professional synergies of digitally-driven modes of production. A more interesting possibility is the structuring of building teams as dynamic, geographically-distributed digital networks of design and production expertise, which change fluidly as the circumstances of the project or practice require. Architects will increasingly find themselves working in an environment of multidirectional digitally-mediated exchange of knowledge among various members of design and construction teams. In the emerging fluid, heterogeneous processes of production, the digital data, software and various manufacturing devices will be used in different ways by different members of the building team, who will often operate in different places and in different time zones.

As architects shift their attention from drawing production to digital information authoring, the software industry has a very important role to play in the transition to emerging digital modes of practice. Instead of adopting a conservative stance, which calls for providing technologies based on prevalent modes of practice, it has to actively engage in developing the tools that support new modes of production. In partnership with the building industry, it must overcome existing social and cultural barriers to technological innovation and must aggressively promote a new culture of use based on a single building model.

Educational institutions are the ones who have the power (and, hopefully, the foresight) to prepare future generations of professionals for the emerging practices of the digital age. We need to start training architects to be master builders again, to understand and re-engage the processes of building through digital technologies.

THE INEVITABLE

As architects find themselves increasingly working across other disciplines, such as material science and computer-aided manufacturing, the historic relationships between architecture and its means of production are increasingly being challenged by the emerging digitally-driven processes of design, fabrication and construction. The amalgamation of what were, until recently, separate enterprises has already transformed other industries, such as aerospace, automotive and shipbuilding, but there has yet to be a similarly significant and industry-wide impact in the world of building design and construction. That change, however, has already started, and is inevitable and unavoidable. The obstacles are numerous but the rewards are compelling if architects can manage to liberate the profession from the anachronistic practices of the twentieth century.

If nothing else, eventually the sheer number of digitally-produced projects will bring about a new way of thinking about architecture and its proper place within the building industry. Many of the strategies and techniques of production, which are pioneered today by Frank Gehry and his numerous less-known, but more adventurous, younger colleagues, will be commonplace tomorrow, just as the material and technological innovations of the nineteenth century eventually became mainstream in the twentieth century.

¹ W. Mitchell and M. McCullough. "Prototyping" (Chapter 18) in *Digital Design Media*, 2nd edition. New York: Van Nostrand Reinhold, 1995, pp. 417–440.

² Howard Davis. *The Culture of Building*. New York: Oxford University Press, 1999.

³ *Ibid.*

⁴ AIA Document A201: *General Conditions of the Contract for Construction*; the AIA's oldest contract document in circulation.

⁵ James Cramer, 2000, <http://www.greenwayconsulting.com/>

⁶ *Ibid.*

⁷ *Ibid.*

⁸ Bruce Lindsey. *Digital Gehry: Material Resistance, Digital Construction*. Basel: Birkhauser, 2001.

⁹ "CATIA at Frank O. Gehry & Associates, Inc.," <http://www-3.ibm.com/solutions/engineering/esindus.nsf/Public/sufran>.

¹⁰ Andrew Cocke. "The Business of Complex Curves" in *Architecture*, December 2000.

¹¹ Dana Buntrock. *Japanese Architecture as a Collaborative Process*. London: Spon Press, 2002.