

## Building Information Modelling (2009)

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Richard Garber

The generic term Building Information Modelling, or BIM, came into use in the early 2000s to designate software for building and construction management and cost control. More recently, under a variety of proprietary names, BIM software has been developed into a fully-fledged tool for design and construction; this *AD Profile* takes stock of this evolution, assessing the implications of BIM for contemporary design, professional practice and, more generally, for design theory and history.

BIM software evolved for the most part independently from the more formal and tectonic experimentations in digital design of the last 20 years. The recent interest it has generated among the design professions may be due to a crucial shortcoming of digital mass-customisation in architecture: file-to-factory technologies are easy to implement at the scale of fabrication, but less so at the scale of construction, because the making of full-size buildings requires plenty of information exchange and coordination among scores of different agents and actors, human and technical alike – each in charge of different parts or aspects of the project. BIM technology was developed partly as a solution to this informational predicament, and in its more recent developments BIM software increasingly serves as an interactive tool for collaboration and participatory decision-making.

Albeit to this day most BIM applications still pertain to optimisation, performance and efficiency in cost and delivery, Richard Garber emphasises the theoretical, as well as practical import of a new tool capable of ‘closing the gap’ between design intentions, architectural notations and material execution – a gap inaugurated in the Renaissance by the very invention of architectural design and of the architectural profession.

## **Optimisation Stories: The Impact of Building Information Modelling on Contemporary Design Practice** *AD* March–April 2009

Over the last 25 years, the broad use of computer software has revolutionised the way we generate and document architectural design proposals. Much of this work has occurred either in visualisation or formal speculation (mainly academic concerns) or in conventional documentation and management (mainly professional preoccupations). This separation between theory and practice is amplified by the relationship between architects and those who build their design proposals. This formerly manual transfer of design documentation via the interpretation of others invites breaks, or gaps, in what should be a continuous and interrelated process of design development and building actualisation. However, these gaps are now closing as new possibilities emerging at either end of the spectrum demand the support of one another – advanced analysis software would not be necessary without design imagination.

Design computing has expanded in scope beyond representation-based documentation to now include analysis, simulation and digital fabrication. These new components allow architects to better understand and manage how their virtual ideas are realised, and to innovate or challenge traditional delivery and construction methods. The synthesis of such technologies and the need for better construction management has led to the emergence of building information models which close the gap and, in turn, promise to revolutionise contemporary design practice.

While current technologies are not sufficiently developed for full-scale buildings to be produced with computer numerically controlled (CNC) hardware, they do allow developed building information models to more precisely assist in the translation of a virtual construct into an actual one. Can a cost-effective paradigm shift be achieved using new computing technologies in architectural design?

The potential of building information modelling (BIM) is that a single, intelligent, virtual model can be used to satisfy all aspects of the design process including visualisation, checking for spatial conflict, automated parts and assembly production (CAM), construction sequencing, and materials research and testing. The model is shared, and contributed to, by all parties involved in the construction of the building, from architects to engineering consultants, contractors and subcontractors. This suggests a paradigm shift in design procedure and teaching that would involve time-based iteration and testing, not only of design potentials, but also of construction in a virtual environment. Indeed information models foster a kind of automatic coordination and collaboration that, partly due to the medium and partly due to the intentions of designers, has not been seen before in the broader building industry. However, this seems less likely to specifically enhance the architect's position as a central hub through which all things pass – a return to the status of master builder – during the design of buildings. Perhaps, more interestingly, these technologies allow for a medium in which notions of creativity and innovation merge through performance operations, cost efficiencies, and material and system simulations that are iterated digitally throughout the design process as opposed to in the field during construction, where finding errors or conditions not properly coordinated could lead to costly expenditures in terms of time and budget.



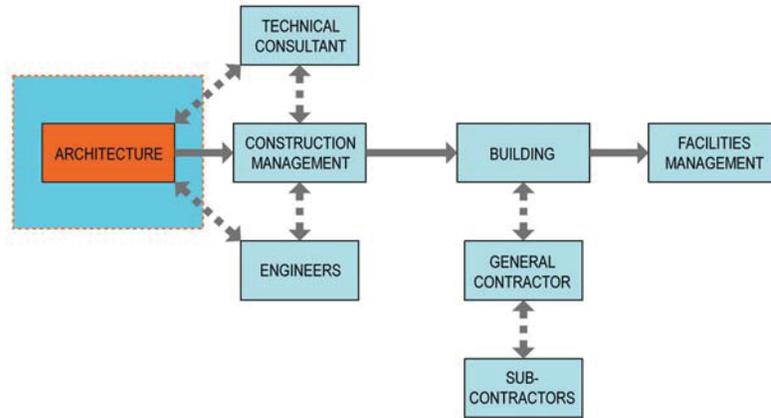
### **Information Models in Contemporary Design Practice**

According to the US National Institute of Building Sciences (NIBS), BIM refers to 'the use of the concepts and practices of open and interoperable information exchanges, emerging technologies, new business structures and influencing the re-engineering of processes in ways that dramatically reduce multiple forms of waste in the building industry'.<sup>1</sup> The institute's work focuses mainly on the further development of integrated product delivery (IPD) and data translation for the streamlined sharing of information between architects and subcontractors, such as structural steel fabricators. Other areas in which it is developing standards include automated code compliance checking (AC3) and construction to operations building information exchange (COBIE).

Many firms are finding attractive information models based on their digital management capacity. As digital databases, these models can control and monitor construction events so as to streamline and refine the construction process itself. There are already numerous examples of how BIM has saved time and made the building process more efficient: one only needs to be reminded of how the geometrically complex Denver Art Museum by Daniel Libeskind was completed in 2005 by the Midwestern US contractor MA Mortenson three months ahead of schedule, and with no change orders during the construction process.<sup>2</sup>

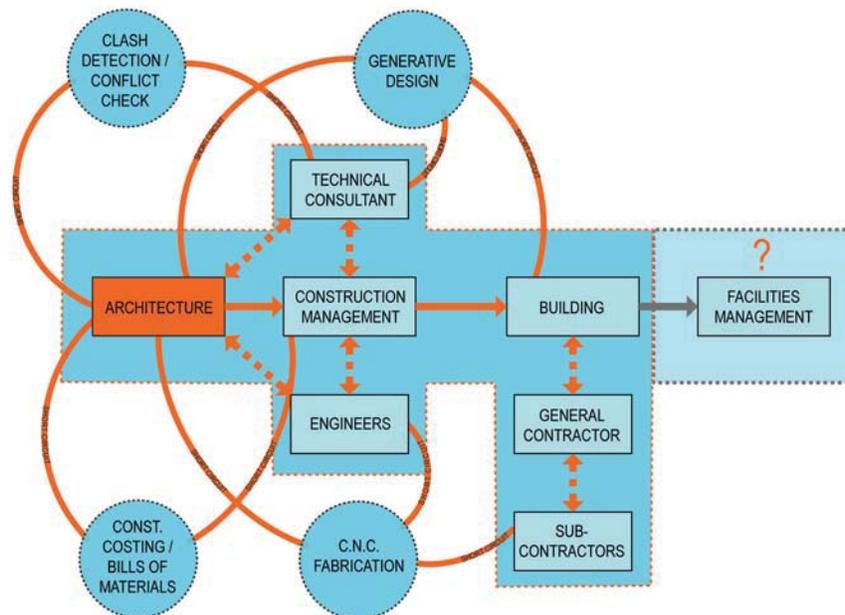


Greg Lynn FORM, Garofalo Architects and McInturf Architects, Presbyterian Church of New York, Queens, New York, 1999. Greg Lynn's Presbyterian Church was 'stick-built'; that is, manually constructed of traditional construction materials that were fabricated and installed based on two-dimensional construction documents and shop drawings, much like a conventional project. However, it became a significant precedent for several of the architects represented in this issue of *AD* as the manual creation of construction documents in a CAD system required the measuring and rationalisation of the three-dimensional components of the virtual model. It was critical even at this early stage of the virtual construction to develop methods for the precise and accurate translation of three-dimensional geometries into a two-dimensional CAD document (profiles, plans, etc). The result is a stunning sanctuary space imagined in a virtual environment that, once actualised, spoke to the merit of such a design process while attracting the interest of a whole generation of young designers. © 2011 Jason Valdina/Received.com.

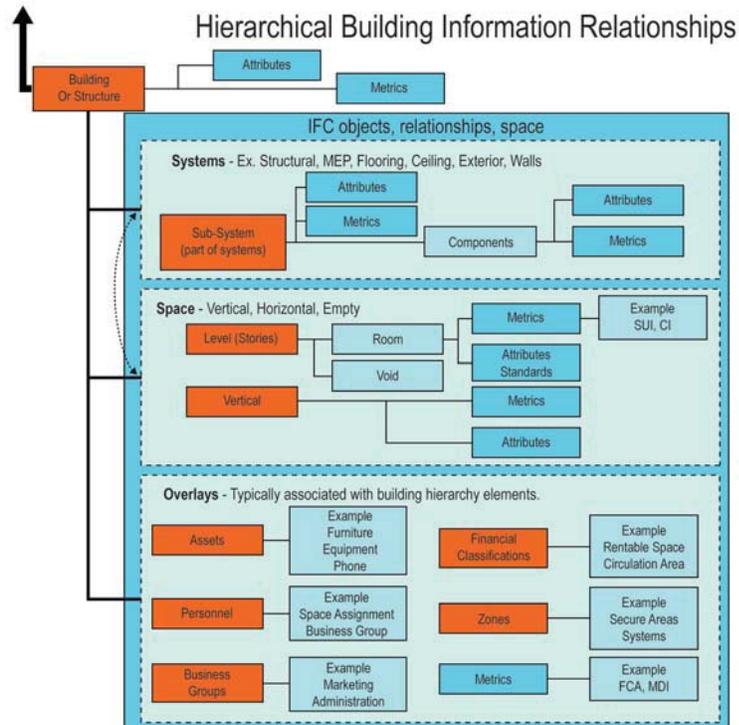


← TRADITIONAL DESIGN PROCESS → ← TRADITIONAL SITE ACTIVITIES AND POTENTIAL FIELD ERRORS →

above: GRO Architects, diagram showing the traditional architectural design process, 2008. In traditional architectural practice, a linear exchange of analogue information facilitated interpretation and the need for clarification on site. In this 'possible to real' paradigm, it was therefore necessary to transmit conventional documentation to others involved in the construction process. The manual translation of quantitative and qualitative building information (bills of materials, component quantities, as well as structural and environmental efficiencies based on rules of thumb) made full coordination of all the construction activities difficult. The result was a reality that was like the possible only through representation. © GRO Architects, PLLC.



← OPPORTUNITY FOR EXPANSIVE DESIGN PROCESS AND FURTHER ITERATION → ← SITE ACTIVITIES AND POTENTIAL FIELD ERRORS →



*above:* National Institute of Building Sciences, hierarchical building information relationships, 2006. The National Institute of Building Sciences, based in Washington DC, has been instrumental in setting building information modelling (BIM) standards in the US and internationally. It has divided the BIM process into an object-based system of Industry Foundation Classes (IFCs): Systems represent the physical entities of the building and can be classified by form (high rise, suspension bridge) or function (single-family residence, courthouse); Space is tied to the physical structure or systems by a boundary definition; and Overlays are the abstract data – organisational, operational, functional, financial, non-fixed assets, resources, personnel, etc – tied to the Systems and Space classifications. Further definitions can be found on the institute’s website ([www.nibs.org](http://www.nibs.org)). © Dianne Davis, CSI.

*opposite bottom:* GRO Architects, information modelling in architectural practice, 2008. In architectural practice augmented by information modelling, virtual translation of data and real-time performance testing become possible. In this new paradigm – the ‘virtual to actual’ – the virtual is already fully real and needs only be actualised by a process of translation from virtual matter to physical matter. Efficiencies of computer numerically controlled (CNC) fabrication, real-time generation of bills of materials and schedules, as well as construction sequencing occur. Through information modelling, the design process becomes augmented and more iterative, and allows for more in-depth collaboration between architects and allied design professionals such as engineers, technology consultants and subcontractors in a nonlinear fashion. Streamlined management of construction projects is not the only impact of these technologies as many information modelling packages contain generative design modules that promise further formal speculation tied to performance. Information models also lend themselves to the life-cycle management of a building, well beyond the conclusion of the design and construction process. © GRO Architects, PLLC.

The ability of an architect, engineer or contractor to simulate construction in a digital model has many merits and uses 4-D, or time-based, operations in what is seen as, perhaps finally, the use of animation for something other than the formal manipulations of the 1990s. Originally conceived of by Greg Lynn and others<sup>3</sup> for its capacity in the design process to allow all geometry to respond to a series of programmable (typically numeric) factors, animation became synonymous with the 'stopping problem'. This term was generally attributed to time-based geometric experiments in which the resulting forms were somehow imprecise because it was difficult to conventionally ascertain why one geometric frame was any more applicable than another: an arbitrariness that quickly branded certain architects and designers as not being grounded in the true problems of design and construction. However, these models were precise in that they were measurable (mass, volume, dimension, curvature) virtual constructs and represented a range of options. This notion of range forms the essence of the parametric experiments possible with BIM systems today: through optimisations of shape, cost, material, orientation and so on, an informed choice can be made from a family of related virtual solutions, and also serves to de-emphasise what perhaps was initially an interest in the formal aesthetic that also emerged from early studies of form generation and animation.

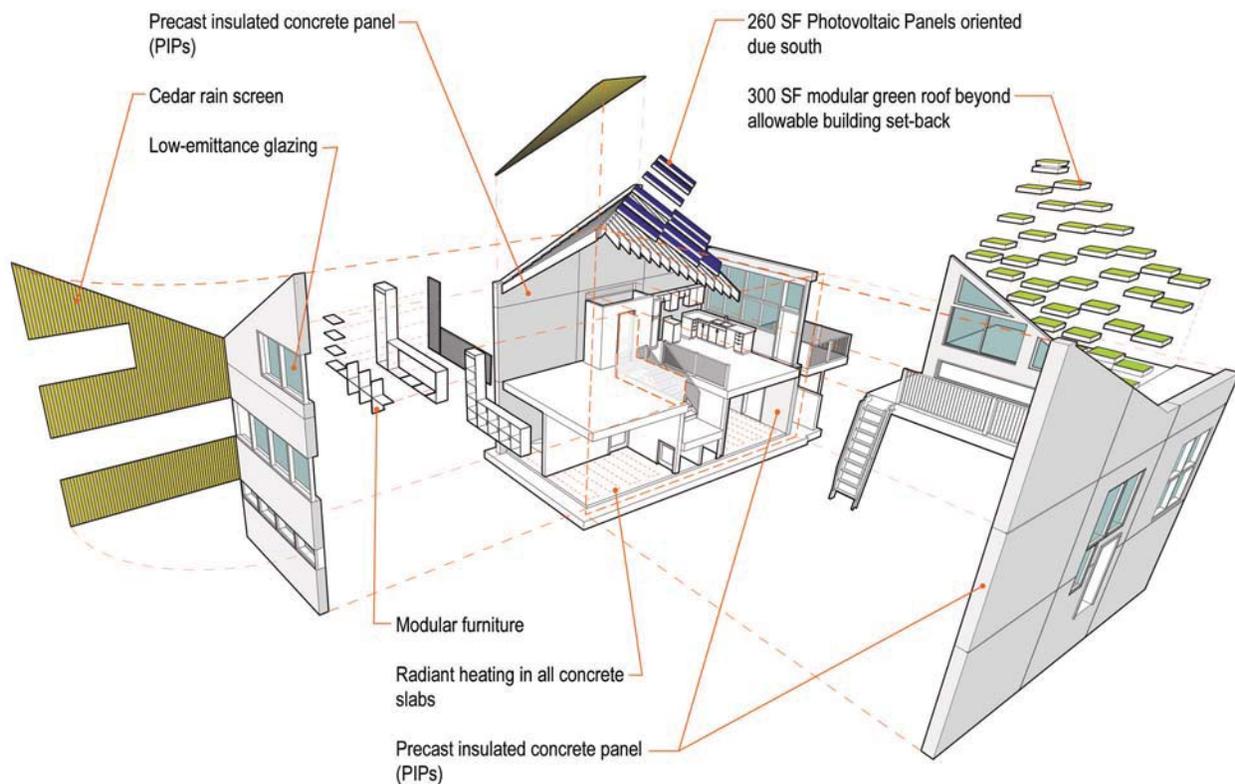
### **Material Simulation and Testing**

Still other capacities of BIM systems, such as clash detection, the generation of bills of materials and real-time construction schedules, and the transfer of digital data to fabricators or subcontractors, are attractive in their potential to optimise the design and building process. If construction can now be controlled through a single model or, more appropriately, a database that can accept information from a variety of sources, design optimisations such as those listed above can be studied in the earlier stages of development. The ability to respond to material or geometric factors such as stress, weight, hardness, volume and area, as well as time-based concerns such as sequence, has allowed designers to apply virtual attributes that yield form. Buildings can be understood according to how they perform as opposed to what they look like.

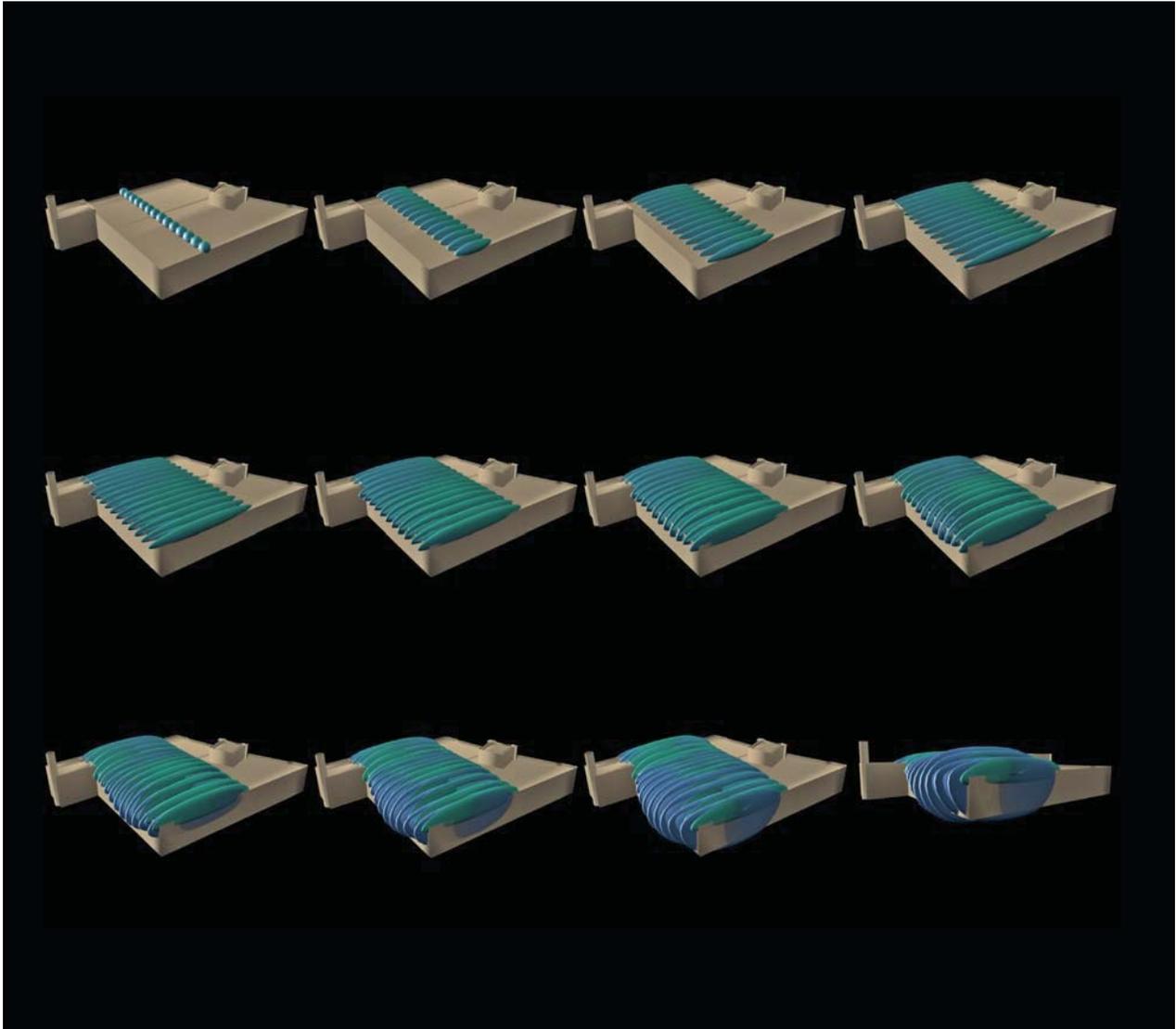
While there is still work to be done on the translation of various types of data into such a model, it is important to recognise that not all information needs to be distributed to the entire construction team at any given time: for example, a CNC fabricator responsible, say, for custom steel connection plates need not be concerned with the size and orientation of supply ducts as long as he or she can be 'digitally assured' that the ducts will not interfere spatially with the plates.

### **External Pressures**

One of the more curious occurrences in the last two decades has been the emergence of new building 'specialists' whose purpose it is to oversee the complex and messy construction process. The impact of these construction managers seems unclear and is in some ways ironic. They are essentially watchdogs employed by owners or contractors to ensure economic and production transparency, yet often make the



GRO Architects, PREFAB House, Jersey City, New Jersey, 2008. BIM systems have two important and interrelated aspects. First, they allow all virtual geometry to be linked to real-time databases for the accurate costing of materials and for ensuring building components are properly integrated. Next, they allow for the smooth transfer of data to the software packages that enable simulation to occur. The PREFAB house was conceived as an economical yet environmentally responsive structure able to generate its own power and utilise efficient materials. In addition to developing a set of construction documents in a BIM system, the information model was translated into environmental analysis software to study criteria such as solar gain and heat loss in winter months, and also into a proprietary software to generate the 3-D formwork for the house's precast-concrete walls. The proprietary software also allows the virtual sequencing of the panel assembly prior to components being delivered to the site. © GRO Architects, PLLC.



Greg Lynn FORM, Garofalo Architects and McInturf Architects, Presbyterian Church of New York, Queens, New York, 1999. The use of animation in early yet sophisticated modelling programs enabled designers to employ time-based operations in the design decision-making process. While these early modelling programs did not have the capability to link information such as material resistance to this form generation, virtual information such as mass and thickness could be extracted directly for material consideration. For the Presbyterian Church of New York, Greg Lynn FORM generated a virtual model that animated an interrelated series of forms for the main sanctuary space of the building. © Greg Lynn FORM.

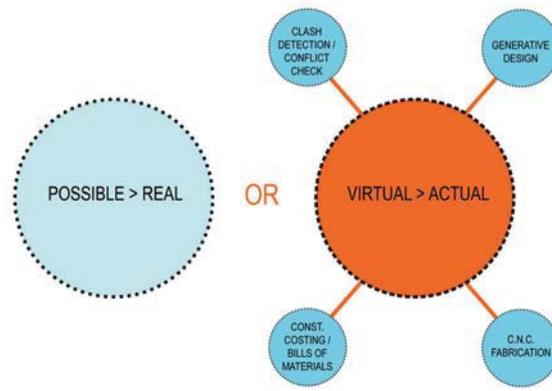


GRO Architects, Best Pedestrian Route, Lower Manhattan, New York, 2007. As BIM systems allow designers to think through problems of construction sequence and assembly virtually, the relationship of design to fabrication becomes much more comprehensive. CNC fabrication from digital files enables different parts to be cut from materials as economically as standardised parts were machined in the 20th century. In the fabrication and assembly of Best Pedestrian Route, a digitally fabricated temporary construction walkway, a series of uniquely shaped aluminium gussets were required to resist the bending moment of the cantilevered roof of the walkway. The gussets were water-jet cut from pieces of 6-millimetre (0.25-inch) and 12.5-millimetre (0.5-inch) aluminium sheets and precisely positioned within pockets that were CNC-routed to the inside faces of the plywood rib geometry. The precision with which the rib assemblies fit together could not have been achieved manually. © GRO Architects, PLLC.

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building management process more complex while also diverting fees away from those involved in the design of a building. The promotion of a more transparent process of checks and balances through information models would thus seem to be an important value-adding capacity of BIM.

The time-based, parametric and generational capacities of many information modelling softwares allow architects and designers to challenge conventional and outmoded construction methods while simultaneously introducing new techniques for organising and creating form and space. Parametric and organisational scripts for form generation take into account material attributes such as weight and maximum curvature so that the tedious process of translating one's design intentions into something buildable can become much more refined. This also offers the potential for the rationalisation of new building forms in much the same way that BIM packages can be used to optimise more conventional typologies or construction methods. Though the generational capacities of these tools are often overlooked, they nevertheless represent a real way of introducing the new organisations necessary to contend with increasingly complex, mixed and various programmes and building types to our constructed landscape.<sup>4</sup>



*above*: Interpretation, or at least discussion, on the project site of the Pavilion Zürichhorn, Switzerland, in 1960. In the possible to real paradigm, interpretation is necessary to construct an actual building from a set of design possibilities. As there is a gap in the transfer of static information between the architect and the general contractor, it is incredibly difficult to ensure the contractor has a comprehensive understanding of the design intent, and the architect of the construction techniques and methods. Interpretation leads to errors in the field, or situations where certain components or construction sequences need rethinking, both of which can be costly. This, unfortunately, has happened to the best of us! Pictured are Willy Boesiger, Editor of *Oeuvre Complète*, City Architect Adolf Wasserfallen, Le Corbusier, Inspector of Public Parks Pierre Zbinden, and the gallery owner Heidi Weber. © Rene Burri/Magnum Photos.

*opposite top:* GRO Architects, diagram showing the virtual to actual paradigm, 2008. In the possible to real paradigm, representations of a possible object or building are produced and transferred to another party for interpretation; because of this disjunction there is no way of ensuring that the possible and the real will be the same. This traditional method has largely been two-dimensional; even with digital design techniques, the computer is used as a representational tool in the generation of renderings (pictures) or 2-D drawings of a building. This method separates the designer from the fabrication or construction process, and can be traced back to Leon Battista Alberti's decree that there should be a separation between the practices of design and making. As such its evolution has largely taken place in architectural schools. In contrast, the virtual to actual paradigm is an emerging method where (digital) material resistances can be tested through simulation. It is based on the translation and/or dissemination of a virtual 3-D construct, an example of which is translation to a CNC machine for direct manufacturing. © GRO Architects, PLLC.

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### **The Virtual to Actual Paradigm**

Though instrumental in closing the gap between design and building, preliminary, or schematic, opportunities are often overlooked in the adoption of parametric building information models in professional practice. Design theorists such as Sanford Kwinter and Manuel DeLanda have both highlighted the paradigm shift, made possible by information models, whereby the previous method of architectural delivery, the 'possible to real', is being supplanted by a new and seamless one, the 'virtual to actual'. In the first, the formulation of the initial design intention was a necessarily cerebral operation.<sup>5</sup> The designer would dream up a form and then represent it as an architectural proposal to which would be attached information about materials, construction methods and so on. Because proposals were generally documented as two-dimensional abstractions of a possible building, they required interpretation by others than the designer to realise the building. As such it was impossible to guarantee that the intentions of the architect would be precise in the built project.

An example of this conventional model in digital architectural design is image mapping, in which representational as opposed to performance-based criteria are used in the selection of an appropriate design proposal. Three-dimensional modelling programs were first used to simulate what a building would look like via libraries of 'materials' (generally bitmapped images) that could be applied with relative ease to preconceived forms. These forms were primarily variations of non-eidetic geometries (planes, spheres, cubes) that had no relation or resistance to the representations of materials they would receive. The outcome of such operations was largely deemed successful if the applied image maps were adequate in texture and scale. Whether brick was a suitable material choice for such a form, or masonry construction appropriate, was usually given far less consideration.

This virtual reality further separated architects from the material process of building. When not linked to a database or library, the bitmapped brick (or grass, granite, or 'purple', for that matter) wall has no properties or attributes that architects must consider in its construction. It has no weight, is unaffected by its height to thickness, and displays no resistance if a second virtual object is placed on top of it. Consequently, it has no reference or attribute data to determine whether or not it can sufficiently behave like a wall.



Douglas Gauthier and Jeremy Edmiston, BURST\* Project LLC, BURST\*008, 'Home Delivery: Fabricating the Modern Dwelling', Museum of Modern Art, New York, 2008. Delivery and erection of the \*BURST House's CNC-cut structurally insulated panels (SIPs) to the exhibition site where they were fastened together. This process is a different take on prefabrication, in that the house arrives on site as a series of parts that are put together like a jigsaw puzzle. It is important to note the difference between this process, in which many unique parts are cut by a CNC machine, and one of mass standardisation where the same parts are assembled by workers on site as a series of repetitive tasks. BURST\*008 used CNC output for efficient mass-customisation, demonstrating how information models can be employed to optimise, simulate and make construction methods more efficient. © Douglas Gauthier, GA and BURST\* LLC.

An often overlooked aspect of the introduction of computing to the design and management of buildings is the necessary break from traditional ideas and methods of teaching architecture. Though we are now some two decades into the digital, one senses that yet another gap between the teaching of new modes of practice using information models and traditional architectural education has been created. Lack of buildability and formal whimsy seem to inform the critique articulated by those who advocate more traditional methods of education. It is important to note, however, that the formal speculations of the last decade partially laid the foundations for the development and adoption of BIM systems in architectural design. When measured against performance or other optimising criteria, these speculations seem to intersect with the more pragmatic management tools and construction simulations proffered by information models.

In the contemporary virtual to actual paradigm, interpretation is no longer required because digital information models are already inherently real. As precise three-dimensional concepts are designed, tested, iterated and optimised in virtual space, they need only to be translated, or actualised, into physical media. A simple example would be a series of panels rationalised on a virtual sheet of plywood to be CNC-cut by a router.

### **Closing the Gap**

The architects, engineers and academics who have contributed to this issue of *AD* have a broad and varied interest in the use of BIM technologies. The scope of the issue therefore covers architectural education, comparisons with historic models of practice, changes in contemporary design practice and the still newer opportunities for optimisation and CNC output. Rather than concentrating on a narrow or specific definition of BIM, the intention is instead to demonstrate how widespread and significant the impact of these technologies on the practice of architecture will be. As clever designers use BIM tools to better optimise, iterate and test their ideas, we will start to see design proposals and built projects that are not only integrated and precise, but truly new.

#### **Notes**

- 1 See <http://www.nibs.org/newsstory3.html/>.
- 2 I described this process in a lecture at the School of Architecture at NJIT on 19 September 2005.
- 3 See Greg Lynn, *Animate Form*, Princeton Architectural Press (New York), 1999.
- 4 See Chuck Eastman, 'Automated Assessment of Early Concept Designs', *Closing the Gap: Information Models in Contemporary Design Practice*, *AD Profile* 198, *AD* 79, March–April 2009, pp 52–7.
- 5 See Manuel DeLanda, 'Philosophies of Design: The Case for Modeling Software', in *VERB Processing: Architecture Boogazine*, Actar (Barcelona), 2002, pp 131–43.

**Richard Garber, 'Optimisation Stories: The Impact of Building Information Modelling on Contemporary Design Practice', Richard Garber (guest-editor), *Closing the Gap: Information Models in Contemporary Design Practice*, *AD Profile* 198, *AD* 79, March–April 2009, pp 6–13. © 2012 John Wiley & Sons Ltd.**