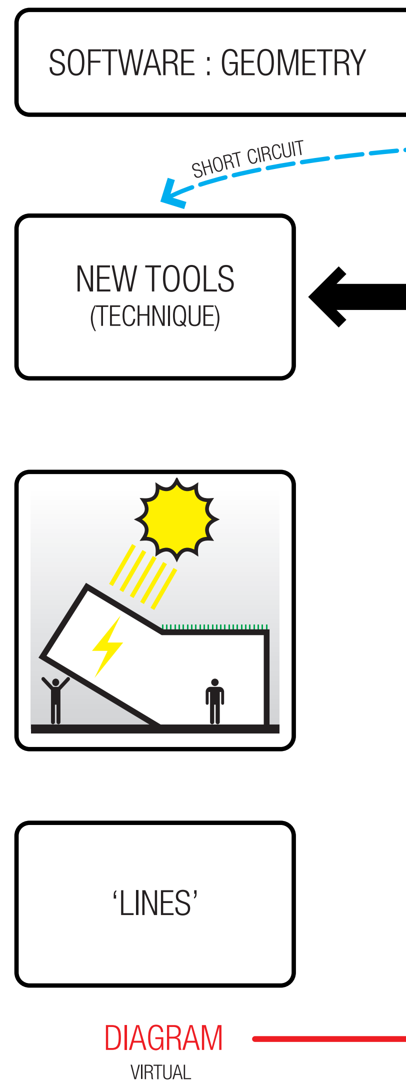
1 INFORMATION MODELLING TODAY

We are in the midst of a virtual re-contextualization or re-embedding that, although it is in no way a return to the premodern contextualization or interlinking of science, religion, art, etc. is nevertheless a stepping beyond the specific autonomies of modernity. As one aspect of this phenomenon one can note that modern technology no longer exists as such – or at least is more and more ceasing to exist. Technology proper has been or is in the process of being supplanted by a post-technology, a hyper-technology, or what I prefer to call a meta-technology. Under such historical conditions the philosophy of technology can be seen as an epoch-specific event that is coming to an end, that is petering out in a kind of exhaustion or displacement. If this is true, then the philosophy of technology may well be in the process of being replaced – not with a philosophy of meta-technology but by philosophy in a general sense that re-incorporates into itself reflection on the meta-technical condition of the postmodern techno-lifeworld.[1]

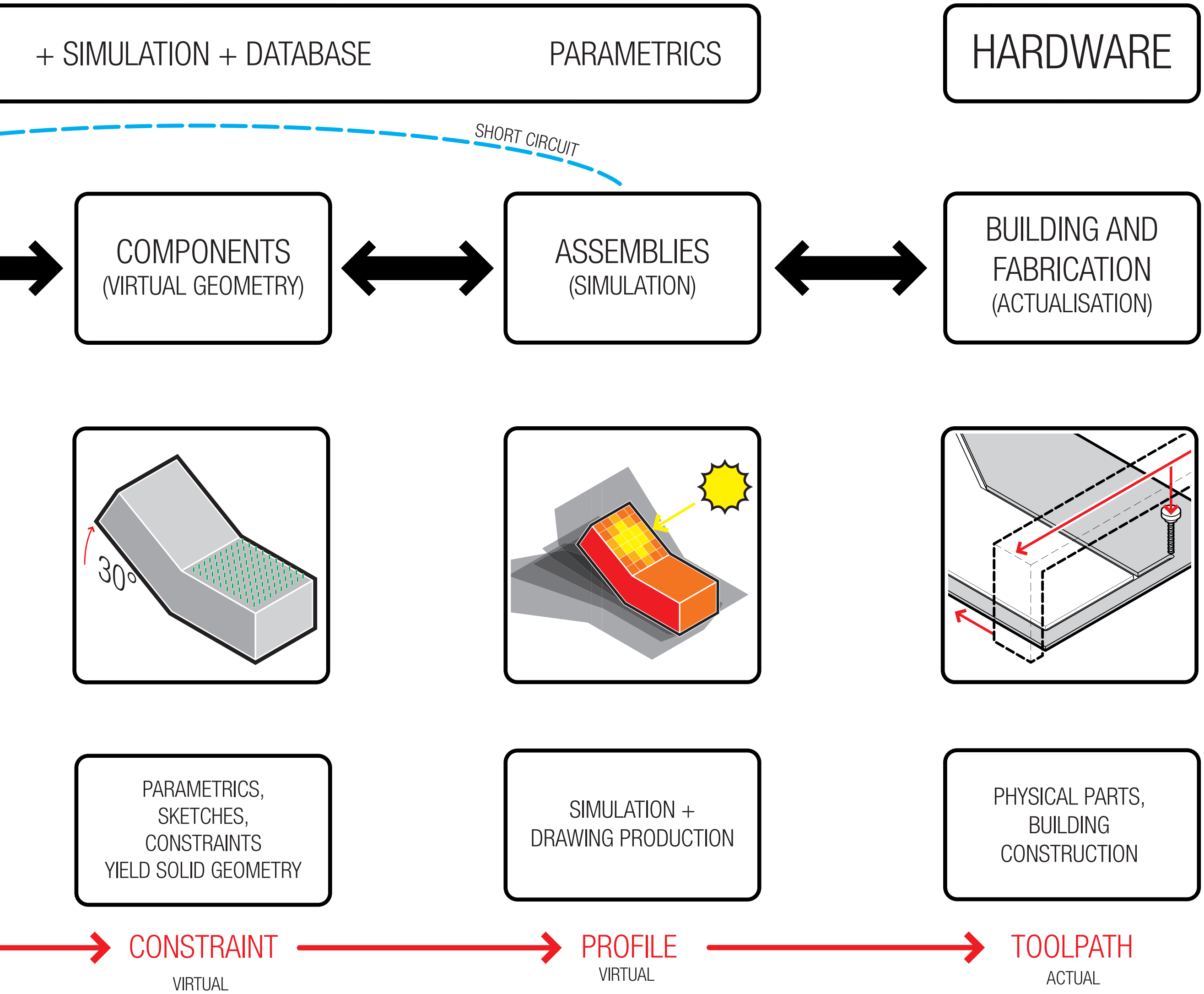
Carl Mitcham, 1995

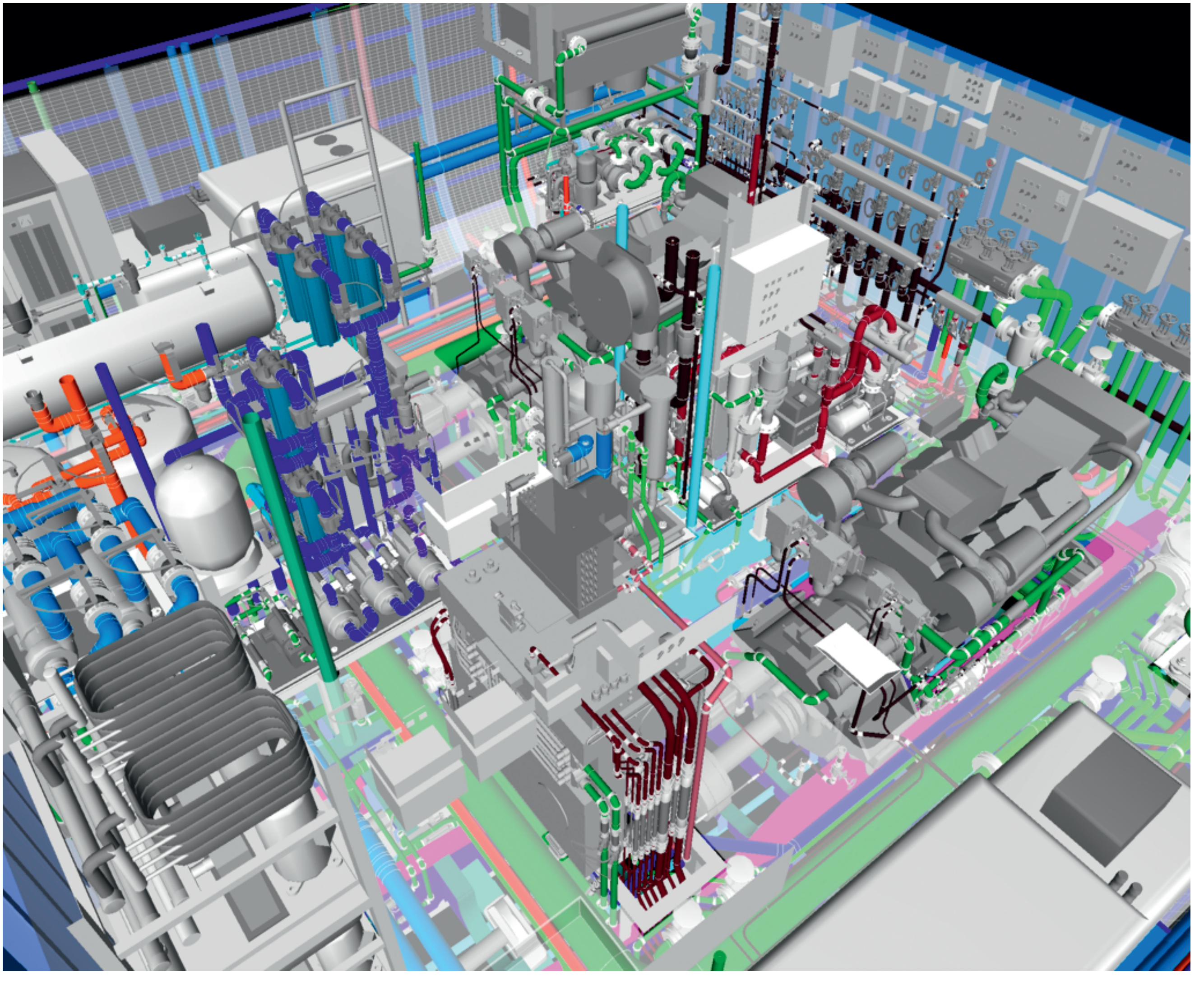
1



Building information modelling (BIM) provides the entire design and construction team with the ability to digitally coordinate the often complex process of building prior to actual construction. As a new design methodology rooted in the technological advances afforded to design practice in the 1980s and 1990s, BIM allows the designer to examine 'many more facets of the project, at the initial sizing stage, using sophisticated computer graphics tools'.[2] This method of construction delivery has become known as *integrated project delivery*, or IPD. Unlike computer-aided drafting, which simply allowed documentation to be *drawn* in the computer, BIM links three-dimensional geometry with real-time databases. Through this single, shared *information model*, the design team can iterate, simulate and test all aspects of construction prior to their operation on the project site. If inaccuracies can be corrected *virtually* prior to construction, material and time savings can be passed on to the architect, general contractor and owner – the three parties typically involved in a construction project. BIM is a technology that not only affects how we construct buildings (the efficiencies and operations), but how we design them as well. For Mario Carpo, 'digitally designed architecture is even more prone to participatory modes of agency, as from its very beginning the theory of digital design has posited a distinction in principle between the design of some general features of an object and the design of some of its

1 GRO Architects, book organisation, 2012
The development of a building information model from design to construction, will be characterised as virtual geometry, the *line*, which begins to accept additional data, or *constraints*, as it is refined from sketch form to building proposal. Two-dimensional drawing production can be accommodated, via the *profile*, or sectioning of virtual geometry, and leads to the generation of the *toolpath* for computer numerically controlled actualisation or analogue construction.





2 Vripack, system piping production information, Sneek, the Netherlands, 2013
The shipbuilding and aerospace industries have relied heavily on two aspects of BIM that are only now having an impact on architectural design and the construction industry. First, ship designers have created integrated virtual models that take into account routing of all systems within a boat hull and allow for checks against collisions. Such models allow for the production of shop drawings used by the fabrication team that include individual part information and bills of quantities. Second, these models allow for both automated and manual prefabrication of these ship systems.

ancillary, variable aspects'.[3] The duality inherent in BIM brings construction and design together under the rubric of a shared information model, while still promoting the architect as a creative director of sorts – who authors design intent, or a project's general features, and then supervises a collaborative team of experts who each input data, or variable aspects, into the model.

WHAT CAN THE DESIGNER EXPECT?

Building information modelling promises that a single, intelligent model can contain and coordinate the following information:

- Construction documentation
- Visualisation (design and construction)
- Material and equipment quantities
- Cost estimates
- 4-D construction sequencing and reporting
- Scheduling
- Fabrication data and toolpaths.

By adopting an information-modelling platform, architects and designers can:

- Visualise multiple design organisations
- Simulate alternatives
- Identify clashes between building equipment
- Communicate design intent three-dimensionally
- Improve productivity.

For David J Andrews, Professor of Engineering Design at the University College of London, 'The general standardizing of software practice, operating systems, data exchange formats and general purpose CAD systems is so pervasive that the practice of design is effectively dominated by its capabilities, which the computer revolution now provides.'[4] Information modelling tools ultimately replace the CAD tools adopted towards the end of the 20th century with an integrated, parametric database that is shared and refined during the design process, taking advantage of the enhanced graphic, memory and storage capacities of desk- and laptop computers. This database – or *information model* – contains specific three-dimensional geometric information such as sizes, areas and volumes as well as: cost data, material and component quantities, zoning analysis, environmental performance and instructions for fabrication and construction. While such a model may 'look like' the three-dimensional visualisations possible in CAD packages, information models contain an inherent design intelligence that fosters collaboration between those on the design team and those who build the design itself. In addition to a three-dimensional modelling environment, information modelling packages include workspaces for sketch design, simulation for sustainability or construction purposes, two-dimensional drawing output and numeric export to spreadsheets or other hardware for scheduling or digital fabrication. Each of these aspects of designing within the building information modelling environment will be explained.

3 Studio Daniel Libeskind with architect-of-record Davis Partnership Architects, extension to the Denver Art Museum, Frederic C Hamilton Building, Denver, Colorado, 2006
By understanding the museum as a virtual three-dimensional construction prior to building, Studio Daniel Libeskind was able to translate the sweeping forms of the building's exterior to interior spaces, such as this contemporary art gallery.

3

A commonly referred-to example of this process is the Denver Art Museum by Daniel Libeskind and a large US general contractor, Mortenson Construction. Though Libeskind developed a preliminary digital model, the contractor invested the time and effort to develop a complete virtual model that contained not only geometric information – like Libeskind's – but also complete '4-D' (time-based) clash reporting and construction sequencing so that the entire building process could be studied virtually before construction began. The investment paid off; the Denver Art Museum was completed in 2006, three months ahead of schedule and with no cost overruns despite the building's daring geometric form. The conceptual ambitions of the designer-author who uses BIM tools still cannot be replaced.

Still, this early success story only begins to describe the potentials of the building information modelling paradigm we have entered. While there have already been several books taking a case-study approach to how BIM promises amplified efficiencies to architects, contractors and owners from a cost-saving point of view, very little has been written about how these tools allow for rationalisation and optimisation of design intentions for architects at far earlier points in the project development process. How the architect as *author* can take advantage of these tools to amplify qualitative intentions that are not necessarily quantifiable in terms of cost savings or more pragmatic efficiencies is an area of BIM that is underexplored. The aim of this book is to further expose pragmatic efficiencies while expanding the notion that BIM allows for an entirely new type of design process using an augmented suite of tools that engage issues of contemporary design.

For Kenneth Frampton, speaking at Yale University in 2010:

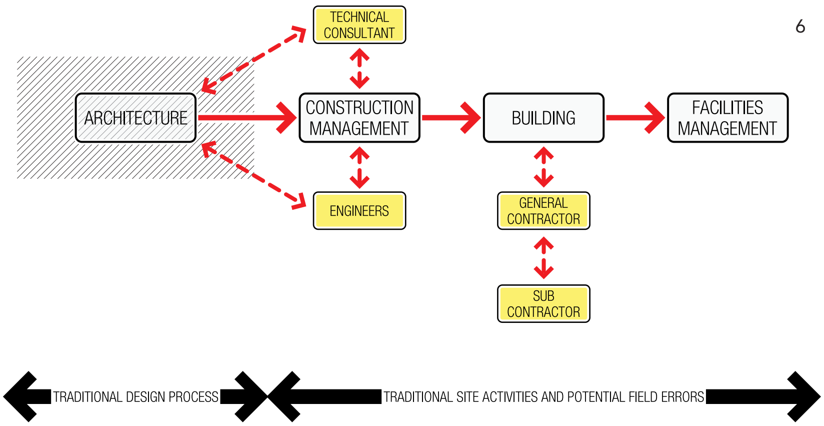
> *Architecture by definition aspires to a state of cultural synthesis and so cannot be made totally consistent in terms of criteria whose sole aim is to optimize production as an end in itself, since at its best, building culture incorporates values that transcend our current proclivity for maximizing the production/consumption cycle in every facet of life. At the same time, the material and operative transformations taking place in the building industry cannot be ignored by the profession, if for no other reason than that many of these innovations are coming from the profession itself.*[5]

Through cohesive integration, BIM has the ability to resolve traditionally oppositional aspects of architecture such as theory/practice, academy/profession and design/construction. This resolution may yield a redefinition of what we think buildings should *look like* and how they should *perform*. As such, this book is organised to accommodate those already adept at using three-dimensional tools, and those just beginning the transition to information modelling. Information modelling and operations are broken down in the following way:

4 Studio Daniel Libeskind with architect-of-record Davis Partnership Architects, extension to the Denver Art Museum, Frederic C Hamilton Building. Denver, Colorado, 2006
For the construction of the 13,500-square-metre (146,000 ft^2) project, the general contractor, Mortenson Construction, adopted BIM technologies and developed the three-dimensional model supplied by Libeskind to support the building's construction. Mortenson's team created building information models of the concrete and steel structure for quantification, formwork design, shop drawings and coordination. The building, and ultimately its design and construction process, received recognition from the American Institute of Architects' fifth annual Technology in Architectural Practice (TAP) Building Information Model (BIM) Awards in 2009.

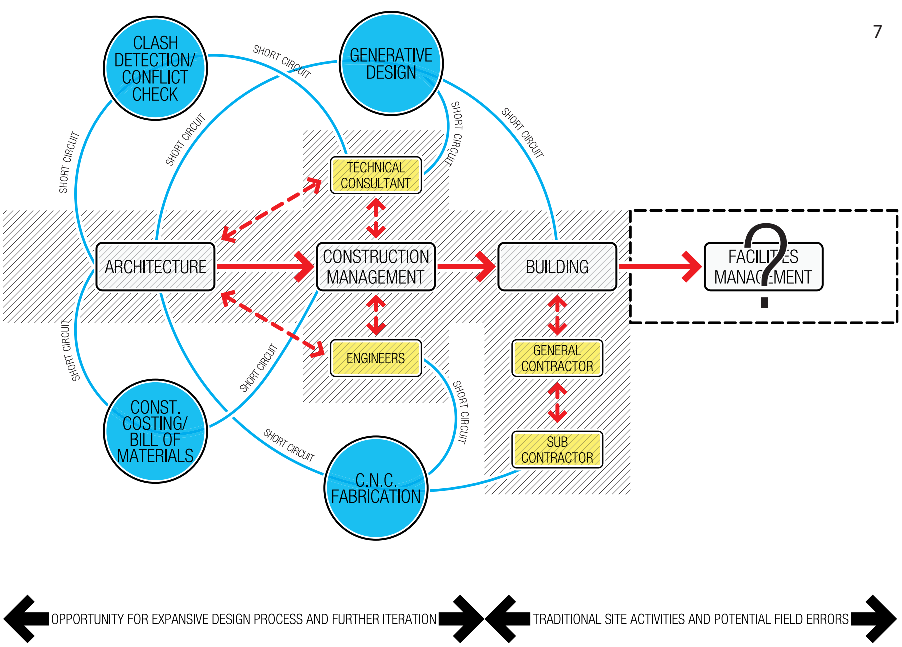
5

6



TECHNICAL CONSULTANT
ARCHITECTURE
CONSTRUCTION MANAGEMENT
BUILDING
FACILITIES MANAGEMENT
ENGINEERS
GENERAL CONTRACTOR
SUB CONTRACTOR
TRADITIONAL DESIGN PROCESS
TRADITIONAL SITE ACTIVITIES AND POTENTIAL FIELD ERRORS

7



CLASH DETECTION/ CONFLICT CHECK
GENERATIVE DESIGN
SHORT CIRCUIT
TECHNICAL CONSULTANT
ARCHITECTURE
CONSTRUCTION MANAGEMENT
BUILDING
FACILITIES MANAGEMENT
?
ENGINEERS
GENERAL CONTRACTOR
SUB CONTRACTOR
CONST. COSTING/ BILL OF MATERIALS
C.N.C. FABRICATION
OPPORTUNITY FOR EXPANSIVE DESIGN PROCESS AND FURTHER ITERATION
TRADITIONAL SITE ACTIVITIES AND POTENTIAL FIELD ERRORS

1 The introduction of new tools and *(virtual)* techniques;
2 The use of parametrics and constraints to produce *(virtual)* building components;
3 The aggregation of these components into building assemblies that can be *simulated*;
4 The translation of virtual components and assemblies to actual buildings, increasingly with prefabrication occurring off-site;
5 The real-time management and simulation of the building construction process and life-cycle management of the building.

The purpose of this organisation is to find consistency with the way different BIM software functions. Specifically, four protocols that compress the gap between design and construction will be explored. These are: generative design; construction costing and bills of quantities; model simulation including clash detection and environmental analysis and computer numerically controlled (CNC) fabrication. By introducing these operations through both historic context and contemporary application, it is anticipated that the reader will not adopt information modelling simply as a way to execute conventional design processes *in a more efficient way*, but consider instead how information modelling technologies allow the architect to operate in truly novel ways to achieve new building efficiencies and organisations. The consequences of how we consider problems of design with these tools will have an impact on what buildings look like and how they perform, thereby charting a new course for contemporary architectural practice.

5 Future Home Technology, prefabricated wall production, Port Jervis, New York, 2013
Increasingly, buildings are being constructed in factories using strict digital controls, much like the shipbuilding and aerospace industries. Future Home Technology, one of several prefabricated building manufacturers that have emerged in the greater New York City metropolitan region, promises customised design and engineering in its 9,300-square-metre (100,000 ft^2) 'state of the art' construction facility. The company, as well as others like it, has adopted BIM technologies to communicate better with architects and streamline the design and production process. Here a series of pre-framed walls are being prepared and will be attached to pre-framed floors.

6 GRO Architects, traditional architectural design, 2012
The traditional architectural design and delivery process tended to minimise time for design operations and to marginalise the impact of the architect on a building project.

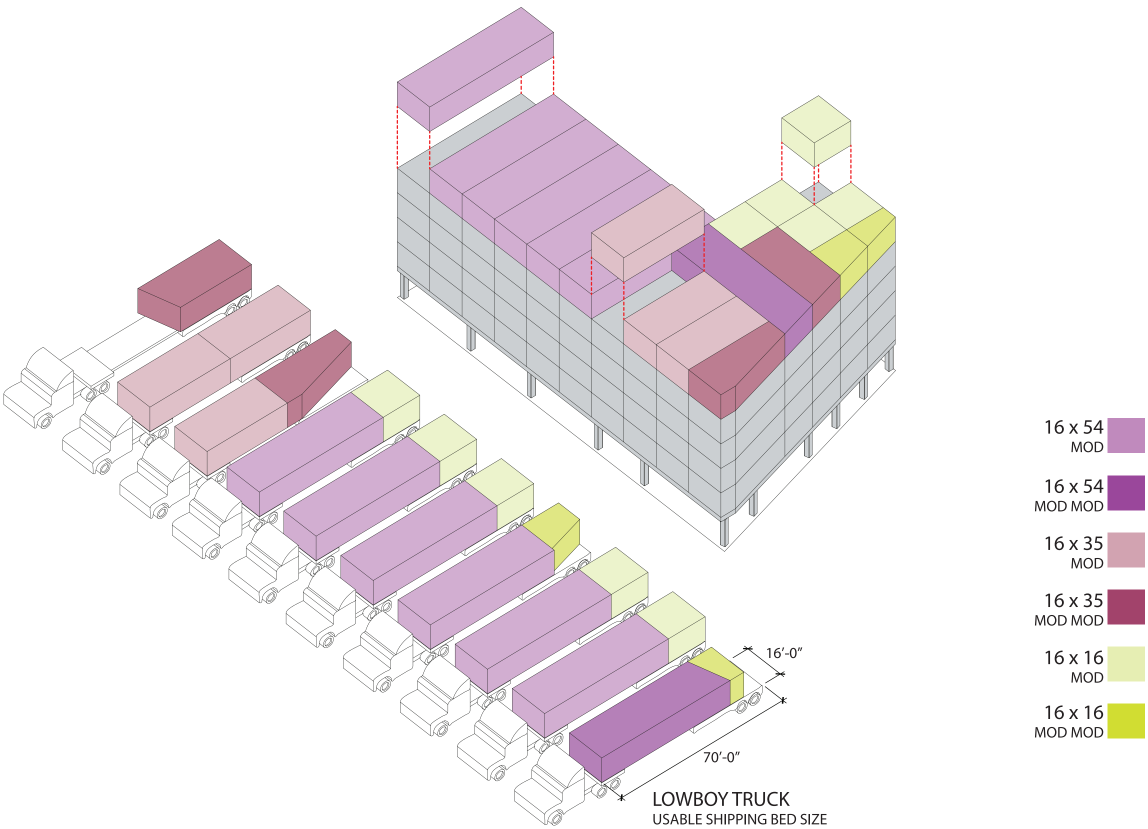
7 GRO Architects, design iteration with BIM, 2012
The architectural design and delivery process utilising information modelling and shared responsibilities. In this paradigm, design operations are iterative and expansive, and data is shared and used in downstream simulation and fabrication operations.

THE DIGITAL DESIGN ENVIRONMENT

As the construction industry has traditionally been slow to adapt to change, advances in digital design and delivery, and the changes they have allowed in building construction, are still novel. As such it is helpful to study how the digital environment has brought about process change in other design-intensive industries. David J Andrews has written extensively on the shift in the shipbuilding industry that digital design tools have enabled. His work will serve as a sounding board for some of the operations introduced here. On a grand scale, he signals that digital technologies have enabled ship designers to move away from engineering design processes and embrace those found in architectural design.[6] In his book *Design in Architecture: Architecture and the Human Sciences*, Geoffrey Broadbent refers to architectural design as 'complex design with human habitat/environment' that is bespoke with a complex procurement process.[7] This classification becomes interesting when it is contrasted with concepts of engineering design as articulated by Vladimir Hubka. Engineering design is 'mechanistic', with machine products and mass-produced components having a 'clear economic basis'.[8]

What becomes clear about the comparison between these two design processes is the multi-faceted, and perhaps open-ended, development of the architectural project. This is not to say that optimisations do not occur within the architectural design process – they do and can at earlier points in the process with information

8


16'-0"
70'-0"
LOWBOY TRUCK
USABLE SHIPPING BED SIZE
16 x 54
MOD
16 x 54
MOD MOD
16 x 35
MOD
16 x 35
MOD MOD
16 x 16
MOD
16 x 16
MOD MOD

modelling technologies – but that optimisation itself is far more complex because of the multiple effects that architectural design must produce. Information modelling operations, in this sense, must then allow the designer to customise the manner in which she/he works with tools – in effect to reinforce the notion of the architect as an *author*. It is the more broad design operations enabled by information modelling, as opposed to its latent management capabilities, that offer the most opportunity to the architect and that will therefore be focused on. Another clear distinction made by Andrews is the bespoke, or mass customisable, aspect of architectural design as compared with engineering design. The reader will find opportunities for mass customisation to be abundant in the design processes described.

8 GRO Architects, multi-family housing project, Jersey City, New Jersey, 2013
Diagram showing variation of prefabricated construction modules in a multi-family housing project. In contrast to 20th-century production ideals, BIM allows for mass customisation of building components that can be developed and rationalised virtually, and then transmitted digitally as a set of instructions for actual building. Increasingly, this has required the designer to take into account building logistics, such as the transport of prefabricated building components to a project site.

BIM: A BLIND EMBRACE OF NEW TECHNOLOGIES?

In addition to the examples and modelling operations discussed, this book is grounded by a conceptual explanation of the paradigm shift to information modelling. The *virtual* building information model is, within computer software, a fully formed thing that needs only to be *actualised*, or made physical. Such modelling operations no longer fall into the trope of representation we are familiar with – that a building is made via the interpretation of the architect's drawings by others. This point will be elaborated in great detail throughout the book.

One of the promises of information modelling software is that architects can better simulate their intentions virtually and exert a far greater degree of control over the translation and actualisation of their work. This notion of control should not be understood as a futile attempt by architects to take responsibility away from others involved in the construction process, but serve to inform and coordinate more completely those allied in the process itself. As a consequence, new digital protocols and techniques to interface with those of the construction industry have emerged, giving us the opportunity to move away from, or integrate variably with, traditional methods of building.

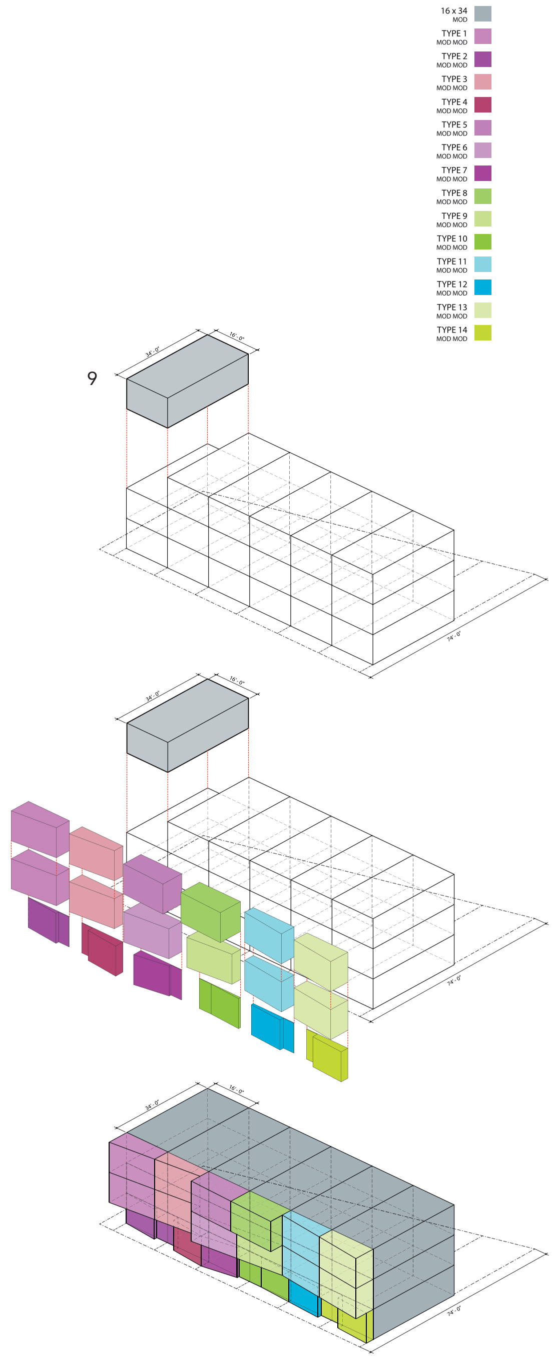
If BIM is indeed a paradigm shift for the profession of architecture and the allied engineering and construction industries, then the information contained herein will be timely and of interest to architects who are transforming their practices from traditional computer-aided design (CAD) tools to more integrated BIM technologies, specifically with an interest in novel and contemporary design techniques that have been made possible through these technologies – particularly addressing the notion of 'authorless results' as Frampton cautions, through the blind embrace of these new technologies.[9] Building, though often the goal of an architectural endeavour, should not be the only reason for information modelling to be broadly adopted. Other aspects of information modelling, such as parametric capacities to constrain or relate geometry or other organisational elements, will prove useful and strategic to designers at project stages well before the selection of a general contractor – a *builder* – is required.

The builder stands to benefit equally from the virtues of information modelling. While new contractual organisations between architects, builders and owners are beyond the scope of this section, it is important to note that during the development of the information model – which is accessible to all parties involved in a building project – attributes such as cost data and construction sequences can be input. These aspects of building, which generally have been undertaken by general contractors or their consultants (cost estimators, subcontractors) will prove in several of the case studies shown in this book to alter the conventional development of a design project.

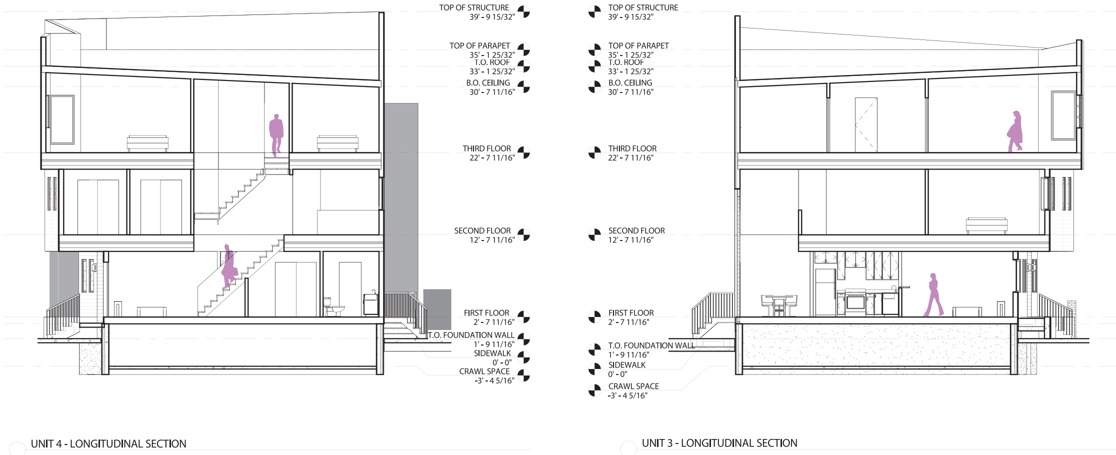
MOVING FORWARD

This book takes a different track from others in that it does not presuppose that everything the designer needs exists within a library stored within BIM software. Instead, it discusses how geometry is built to take on specific attributes, thereby advocating the creation of custom libraries when called for. The Carl Mitcham quote that opens the chapter is timely for several reasons. First, it was written in 1995, the year I graduated from undergraduate school and it is quite incredible to understand how the practice of architecture has changed since then, specifically through information modelling technologies and the impact they have had on the design process. Next, it makes distinctive the difference between the current landscape of technology and the one that existed during the rise of humanism in the early Renaissance – a time that many look to specifically when linking information modelling concepts to the activities of the master builder. The possibility to put forth more comprehensive and integrated designs for buildings, through software, does have similarities with the work done by the master builder – usually an artisan trained in the guilds who spent much of his entire career on the site of a single construction project. Finally, it suggests that a post-technological milieu 'reincorporates into itself reflection', or perhaps intuition, that can reposition the use of technology to the hands of the designer-author as opposed to the technical consultant or draftsperson. That technology, specifically technologies used to support architectural design, has developed to a point where it is flexible enough to be engaged within intuitive design strategies that foster novelty.

In his 2012 book *Future Perfect: The Case for Progress in a Networked Age*, Steven Johnson suggests a phenomenon he calls 'peer progressivism' in which problems are solved incrementally by many, in a decentralised way not unlike web networks.[10] This is a useful way to think about a design and construction team developing BIM, where specialists can add to the model within their scope and expertise. This has interesting implications for authorship, but instead of BIM simply giving way to 'design by many' scenarios, it seems the architect or designer, by imparting design intent, can guide the development of a building information model while still relinquishing a certain amount of the control traditionally associated with the development of a building design.



9



10

9 GRO Architects, modular housing project, Jersey City, New Jersey, 2013
BIM makes mass customisation of building projects possible in a variety of ways. In a separate housing scheme, GRO Architects uses a standard 4.9 x 10.4-metre (16'–0" x 34'–0") unit module, optimised for shipping, and then attaches a series of differentiated 'clips' to provide interior distinction between units and bring variation to the building facade.

10 GRO Architects, modular housing project, Jersey City, New Jersey, 2013
Unit sections, cut from the building information model, show differentiated living spaces and variation along the building facade. Ultimately, two-dimensional drawings such as these are still required in most jurisdictions in the United States and Europe, but are less critical to the construction process, especially when buildings are prefabricated, or manufactured off-site.

NOTES

1 Carl Mitcham, 'Notes Toward a Philosophy of Meta-Technology', *Society for Philosophy and Technology*, D Baird (ed), Nos 1–2, Fall 1995.
2 DJ Andrews, 'A Comprehensive Methodology for the Design of Ships (and Other Complex Systems)', *Proceedings of the Royal Society: Mathematical, Physical and Engineering Sciences*, Vol 454, No 1968 (8 January 1998), p 194.
3 Mario Carpo, 'Digital Style', *Log* 23, Fall 2011, p 47.
4 DJ Andrews, 'Simulation and the Design Building Block Approach in the Design of Ships (and Other Complex Systems)', *Proceedings of the Royal Society: Mathematical, Physical and Engineering Sciences*, Vol 462, No 2075 (November 2006), p 3416.
5 Kenneth Frampton, 'Intention, Craft, and Rationality', *Building (in) the Future: Recasting Labor in Architecture*, P Deamer and P Bernstein (eds), Princeton Architectural Press (New Haven), 2010, p 31.
6 Andrews, 'A Comprehensive Methodology for the Design of Ships', p 188.
7 Geoffrey Broadbent, *Design in Architecture: Architecture and the Human Sciences*, John Wiley & Sons (Chichester), 1973.
8 Vladimir Hubka, *Principles of Engineering Design*, Butterworth-Heinemann (London), 1982.
9 Frampton, 'Intention, Craft, and Rationality', p 30.
10 Steven Johnson, *Future Perfect: The Case For Progress In A Networked Age*, Penguin Group (New York), 2012, p 48.

IMAGES