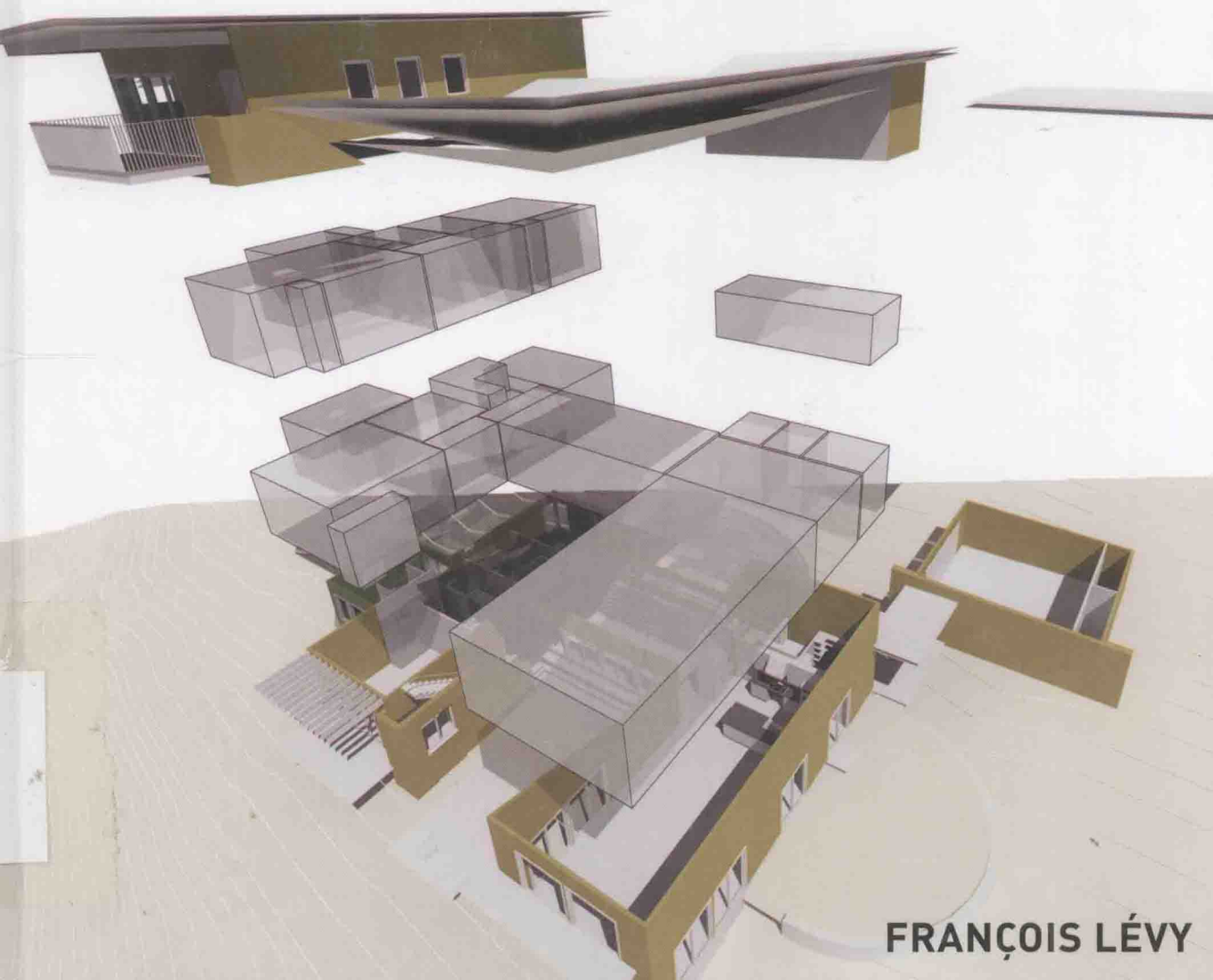


BIM

**IN SMALL-SCALE
SUSTAINABLE DESIGN**



FRANÇOIS LÉVY

BIM

IN SMALL-SCALE
SUSTAINABLE DESIGN



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Pour Milo. Tu serais frère.

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Building Information Models and Modeling

Rapid developments in building design and analysis software over the last decade, coupled with advances in desktop and laptop computational power, have led to the emergence of new digital models for the design and documentation of buildings: virtual buildings or building information models (BIM). Thanks to these advances, BIM-authoring software applications combine three- or four-dimensional models with imbedded, intelligent building objects related in a contextual database. An inescapable buzzword these days in the practice of architecture (and among other building professionals), BIM may commonly mean both *building information modeling* (the process) and *building information model* (the digital artifact). In this book, I use *BIM* (alone) to refer to the modeling process, whereas the model itself I call somewhat redundantly the *BIM model* or ArchiCAD's *virtual building*.

For example, a BIM column is not merely depicted as a two-dimensional representation or three-dimensional extrusion, but exists in the model as an intelligent object that “knows” that it is a column. Contrast this with a column drawn conventionally in plan: increased line weight and perhaps poché allow the user, thanks to established graphic conventions, to *infer* the meaning of four lines which are themselves “dumb” (both in the sense of unintelligent and mute).

As a result of BIM's data-rich 3D modeling, various design disciplines can extract and manipulate relevant tabular or graphical building views such as reports and drawings. Such an approach can

improve building construction and operational performance, increase design efficiencies, and foster an integrated design workflow, among other benefits.

The cost of buildings

Trends in global climate change are correlated with carbon emissions, in that the cost of hydrocarbon fuels upon which world economies are largely dependent is trending upwards, and geopolitical instabilities abound in oil-rich regions of the world. Reducing our carbon emissions sufficiently to slow global warming will require far more radical changes in energy use than most political and corporate leaders will acknowledge; reversing it in the near term is probably impossible. At the time of this writing, the catastrophic and anguishing deep-sea oil spill in the Gulf of Mexico has once again drawn the world's attention to the true costs of our society's dependence on hydrocarbon fuels. And startlingly, 48 percent of US energy expenditure today is devoted to the building sector—it is roughly evenly divided between commercial and residential structures, including energy costs of materials. Given the above, there is a real and meaningful environmental impact that building design professionals will have on the state of the world in the coming decades.

Like BIM, sustainable design is also often seen as an approach more appropriate to large projects, again where design fees can absorb the requisite additional research and design innovation. This perception disregards that residences represent over 20 percent of American energy consumption; our

houses therefore make a considerable contribution to our societal carbon footprint and the depletion of our energy resources. Energy efficiency in housing is thus ignored at our peril.

Furthermore, large buildings are typically internally load dominated, whereas small projects are envelope or skin-load dominated. That is, climate and how we design for it has a much larger impact on a small building's energy consumption than it does for a large building's. Therefore, having good quantitative data is essential for architects to make more intelligent choices about how they design all projects—even small ones.

See, change

BIM is a *design environment* that requires that the designer reevaluate the practice of architecture. Distinguishing "design environment" from "design tool" underscores the reality that BIM represents more than a single tool or software application. Rather, BIM requires a complete shift in the way one goes about the design process.

At the very least, with BIM, buildings are modeled rather than drawn. This may seem very obvious, but the implications are profound. Modeling represents a radical departure from the way we architects have traditionally undertaken the work of our profession for centuries. This not only represents a change in the mechanics of our work, but I contend it is a shift in the cognitive processes that accompany and ultimately drive that work. We work differently, and as a result, probably think differently, too. Furthermore, while modeling decisions may be deferred (a floor, for example, may be represented as an undifferentiated slab), it is difficult to ignore conditions entirely ("the model doesn't lie").

As a result, *design decisions are evaluated based on 3D model views as well as from 2D projections of that model.* The former take the form of perspectives, isometrics, orbital flyovers, fly-throughs, perspective sections, exploded views, and so on. The latter are "drawing" views that may appear to conform to the graphic conventions of traditional plans, sections, and elevations, but in fact are just that—views of the ubiquitous model.

Because of the completeness of the virtual building, extracting views (such as elevations and sections) is nearly trivial—generally a matter of a few clicks of the mouse. As a result, *design development and construction documents are produced far more rapidly* than in the traditional architectural process of constructed drawings. This production efficiency has significant effects. As discussed in greater depth in Chapter 1, by necessity more design decisions are taken earlier in the project. This so-called front-loading (or left-shift in the design phases timeline) of the design process requires that all major geometrical relationships in three dimensions be established earlier. However, the resolution of the details of those relationships may be deferred, as noted above. The practice of architecture is necessarily affected. Workloads and fee structures must be reevaluated in light of a new paradigm of more time spent in schematic design (SD), and less time spent in the construction documents (CD) phase.

With the possibility to explicitly model structural and mechanical components (and ready-made tools for doing so with relative ease), there are *greater opportunities for coordination and collaboration* between architects and engineers. For the architect, an intelligent model helps ensure better coordination of other disciplines. Automatic clash detection—inspecting, analyzing, and alerting the user to undesired interference between model elements—is a BIM feature that originated in automotive and aerospace design software. Clash detection requires a data-rich model to distinguish colliding supply and return air ducts, for example, from a branching supply duct; or to properly identify a column and beam connection as a desirable "interference" rather than as a "clash." Further, common data exchange formats like buildingSMART International's industry foundation classes (IFC) create opportunities for more open exchange of models between architect and structural and mechanical engineers. Conversely, this has given rise to as-yet unresolved issues such as those of model ownership. Nevertheless, BIM and integrated project delivery (IPD) facilitate a more

collaborative approach to design that admits structural and mechanical issues as potential design influences rather than mere afterthoughts.

Finally, and the brunt of this book's objective, BIM creates opportunities for the *quantitative assessment of design options*. That is, the data bound to the virtual building model can be defined, analyzed, and parameterized by the designer, with the ultimate goal of positively influencing building performance. As a practicing architect aspiring to produce work of relevance and beauty, I have a vested interest in finding forms that support high performance buildings and are expressive of that performance.

BIM for the rest of us

For these reasons, I am advocating the somewhat contrarian position that BIM is appropriate as a *design environment*. Architectural design is, after all, a process of proposing and evaluating alternative spatial, geometrical, and material solutions to a stated problem of the built environment. Traditionally qualitative evaluation has been performed in real time, whereas quantitative analysis is often deferred. BIM, if used as I propose in this book, potentially allows quantitative analysis in real time.

I must emphasize that in spite of popular perception, BIM methodology—and the shifts it entails—are applicable to projects of all scales. Small-scaled projects are no less prone to erroneous quantitative analysis. As small buildings are skin-load dominated rather than internally load dominated, their morphology is most impacted by climate. Indeed, thanks to the greater influence of climate on such buildings, they may benefit all the more from “climate indexing,” whereby building massing, geometry, fenestration, envelope and interior materials, and passive strategies are specifically tailored to the building's region and site.

Largely seen as a design and documentation methodology (and ultimately a social convention) rather than a specific technology, BIM promises to allow building designers and stakeholders to leverage greater efficiencies from digital files through

the use of such data-rich building models. Almost universally assumed to be appropriate to large projects with fees to support the “left-shift” in the design process, BIM is often ignored in the context of small projects by many practitioners and software developers. In most instances the BIM workflow is promulgated for large firms and large projects, the supposition being that small firms and projects can't sustain the presumed up-front labor costs that BIM implies.

Yet the production benefits that large firms realize from BIM are also translatable to small firms and projects. Most BIM applications include parametric objects that are suitable to building technologies appropriate to buildings of a variety of scales. From personal experience I can vouch that production efficiencies that I have consistently realized—even on tiny projects of a few hundred square feet—have paid for more time spent on other aspects of design, or allowed me to deliver projects at lower fees, or both. The “left-shift” that I refer to elsewhere is very much real.

According to the Boston Society of Architects, 80 percent of US architecture firms are comprised of six or fewer architects. Increasing the penetration of BIM and sustainable design practices into small firms will be helpful in counteracting the schism between small-firm and large-firm practice. As a practicing architect and university lecturer, I have taught building technology, BIM, and design courses. In my experience, BIM in the context of small architectural projects is a much-neglected topic. I know from personal experience that the assumption that BIM is only appropriate to large projects is false, and that small firms can reap tremendous benefits in sustainable design and production efficiency from a properly integrated BIM work process.

Historically, architects in a variety of firm types all adhered to a similar set of work and documentation conventions; this has been true even to the extent that architects from different regions or countries could understand each other's documents, variations in building technologies notwithstanding. Indeed, the profession is practiced universally to the extent

that it is quite common for architects to gain their architectural education in one country but develop their early career in another, and, at times, practice in a third. As both BIM and sustainable design gain a greater foothold in the architectural community, cultural and technological differences in the practice of architecture in large and small firms may only increase, undermining the universality of architectural training. Such a schism in the architectural practice is undesirable as it further fractures the profession into increasingly specialized niches.

I further contend that BIM is appropriate for sustainable design. There are currently two general approaches to designing for sustainable projects, each with distinct advantages and drawbacks. A *prescriptive* approach, taken by some aspects of Leadership in Energy and Environmental Design (LEED) for example, dictates the measures to be taken to achieve sustainability. Such prescriptive measures serve as proxies for actual building and occupant performance.

Performance design guidelines, on the other hand, require that an aspect of building operation be modeled as a prediction of actual behavior. (LEED also has performance guidelines.) The detailed modeling required is well beyond the scope of BIM applications, requiring building energy performance analysis using dedicated energy simulation software. The BIM model may be exported to the energy modeler, however (See Chapters 1 and 11). Some of the benefits of both prescriptive and performance measures can be attained within BIM, however, through the quantitative analysis techniques that I describe in this book. The benefit of early analysis—even as early as conceptual design—is that it allows the most influence on building performance with the least effort. BIM's adaptability is compatible with performance-driven (sustainable) design. BIM becomes a sustainable design environment, then, as it potentially integrates quantitative analysis in the design decision-making process.

What this book is, and isn't

My challenge has been to pen a book that is a useful guide to small- and medium-sized firms that hold

a commitment to sustainable design and are contemplating or undertaking the transition to BIM. As such, I've had to walk a fine line between being too general and too specific. A book that is too broad might give an interesting, even thought-provoking, overview of the relationship between BIM, skin-load dominated buildings, and small-design practices. But without a highly practical perspective on the topic, it might be of little useful relevance to the practitioner and remain a largely academic exercise. While a theory of BIM is of enormous interest (and essential on some level), it may have little application for most users.

On the other hand, a text that is too detailed, with step-by-step instructions, screenshots, and itemizing particular tasks, might seem attractive, but ultimately would be too limited. Such a book would be more or less a software manual. While this might suit some BIM users, this approach has several shortcomings. Aside from many software users' disinclination to read them, "software manuals" are not relevant to users across a spectrum of proficiencies or at various stages of BIM implementation. By their very nature, manuals must address a certain level of user with certain skills. Second, manuals naturally must address users of a particular software platform. While it's true that Revit, for example, enjoys a large market share, it may not be the software of choice for all users, and there are several other viable alternatives (see Chapter 2). Third, a software manual is quickly outdated. BIM is a rapidly evolving environment, so even a book that is not tethered to a particular release will need to be updated. But a manual is reference for one release cycle (about a year), after which it just takes up shelf (or disk) space. Finally, a manual focuses on tasks, not principles. These tend to be limited to a particular application of the technology, rather than leading to a deeper understanding of the appropriateness of that technology.

Fundamentally, then, this book is meant as a guide. You should be able to read the relevant chapter(s) and then apply the material to actual design projects using the content as a model. Naturally, this will require that you refer to your

software's documentation for the particular tasks required to implement these strategies. I have made efforts to be as comprehensive as possible; a scan of the table of contents will reveal a broad range of sustainable design topics. It will be the rare project indeed that makes use of all aspects of this book. Certain topics will be more or less relevant to a given building given climate, program, site, and so forth. The designer using this book should, as always, use professional and practical judgment in determining the applicability of a topic or technique. Don't expect that in order to design sustainably or design with BIM all aspects addressed here must be applied.

Finally, I should emphasize that in spite of the pervasive discussion of quantitative analysis, the host of other criteria that form the basis of design do not thereby go away. Your training, experience, aesthetic, and qualitative judgment are all still in play. It is not a matter of either BIM and sustainability or purely architectural design; it is a "both and" relationship. You are adding a tool, albeit a powerful

one, to your repertoire. Your trusted old tools are not going away, and indeed they must not be neglected.

A word on the case studies

Each chapter concludes with a case study of an architecturally notable project whose designers have used BIM as a parametric design tool for sustainability. Given the complexity of building performance and variety of software applications available, the methods suggested in this book are by no means exhaustive; many other approaches for performance-based design informed by quantitative analysis are possible. I have attempted to draw from a variety of case studies representative of a wide range of climatic, geographic, and architectural responses to design. As a result, the methods used in the case studies do not necessarily perfectly follow the methodologies outlined in the chapter. This only further demonstrates the vast flexibility and usefulness of BIM, and an evolution of "best practices" for this emerging design environment.

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BIM and Sustainable Design

Having established in the broadest terms the purpose and goals of this book in the Introduction, later chapters will discuss in detail the specific strategies the designer may employ to effectively use building information modeling (BIM) in the design of sustainable, skin-load dominated buildings. Beforehand, however, it is important to define BIM in greater depth, while considering its advantages and limitations (both perceived and real). We will also discuss BIM in the context of the design process, as well as consider its various other roles presented in later chapters. Finally, this chapter, like all others, will conclude with a relevant case study project.

The emergence of Building Information Modeling

Historical context

For centuries, master builders and architects have relied on drawings as an inventive and analytical medium, and to convey instructions to building trades. Vitruvius mentions drafting in *De Architectura*: through geometry the architect's "delineations of buildings on plane surfaces are greatly facilitated." While little medieval construction documentation is extant, it is known that drawing was used to work out and illustrate the proportional system of cathedrals of the day. Models were apparently also not unknown: building models are depicted in medieval ecclesiastical art, and Brunelleschi had a 1/12th-scale model of the Florence Cathedral constructed prior to the construction of the actual building. The extensive technical expertise of historical craftsmen and

tradesmen, combined with established and fairly static vernacular building practices, reduced the need for extensive construction documents. Generations of buildings were constructed with little more than a few drawings and a pattern book of carpentry and masonry details. By the eighteenth century, drafting with specialized steel nibs on prepared surfaces, more or less as it had come to be practiced in my lifetime, had come into being. Such technical documents consisted of precisely constructed drawings executed on vellum, at times watercolored for aesthetic and communicative effect. Examine a Beaux-Arts elevation and marvel both at the beauty of its rendering and the remarkable paucity, by modern standards, of separate details.

The advent of computer-assisted drafting (CAD) did little to change the nature of drawing. It may seem surprising to claim that CAD is similar to eighteenth-century drafting, but consider that CAD drawings are, for the most part, manually assembled. The gestural tasks involved in their construction may be vastly different from those associated with inking vellum, but the cognitive and social processes remain largely the same. In both cases, the architect must manually construct and coordinate various orthographic views—plans, sections, elevations, and details—of a hypothetical building (Fig. 1.2).

Moreover, over a century ago, buildings had none of their construction budgets devoted to mechanical and electrical systems, simply because those systems did not exist; today it is common for about a fifth to a quarter of a building's construction

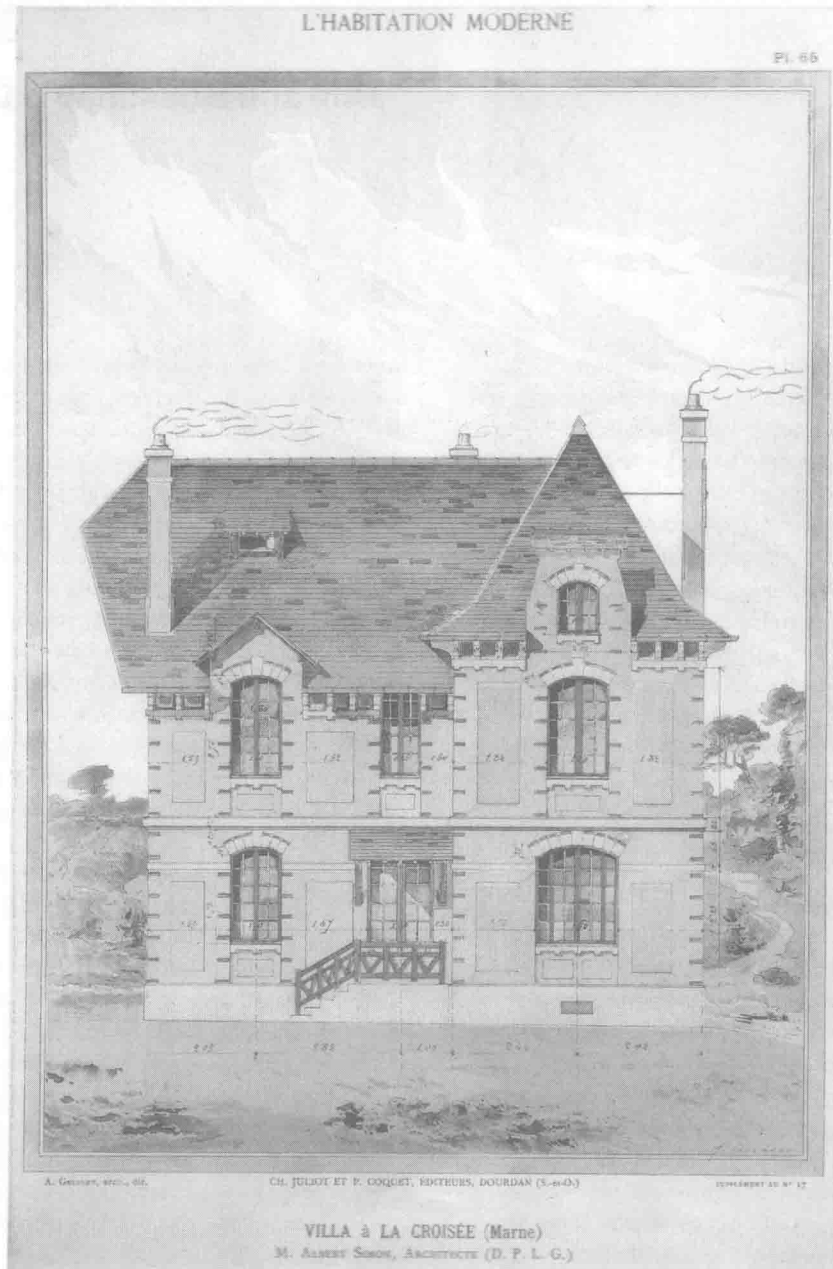


FIGURE 1.1 A late nineteenth- or early twentieth-century elevation is both extremely expressive of design intent and carries very little detailed constructible information. This type of drawing embodies several social factors from a highly artisanal labor pool to a lack of pervasive litigiousness. Note the minimal dimensions.

Albert Simon, architect, from the author's private collection.

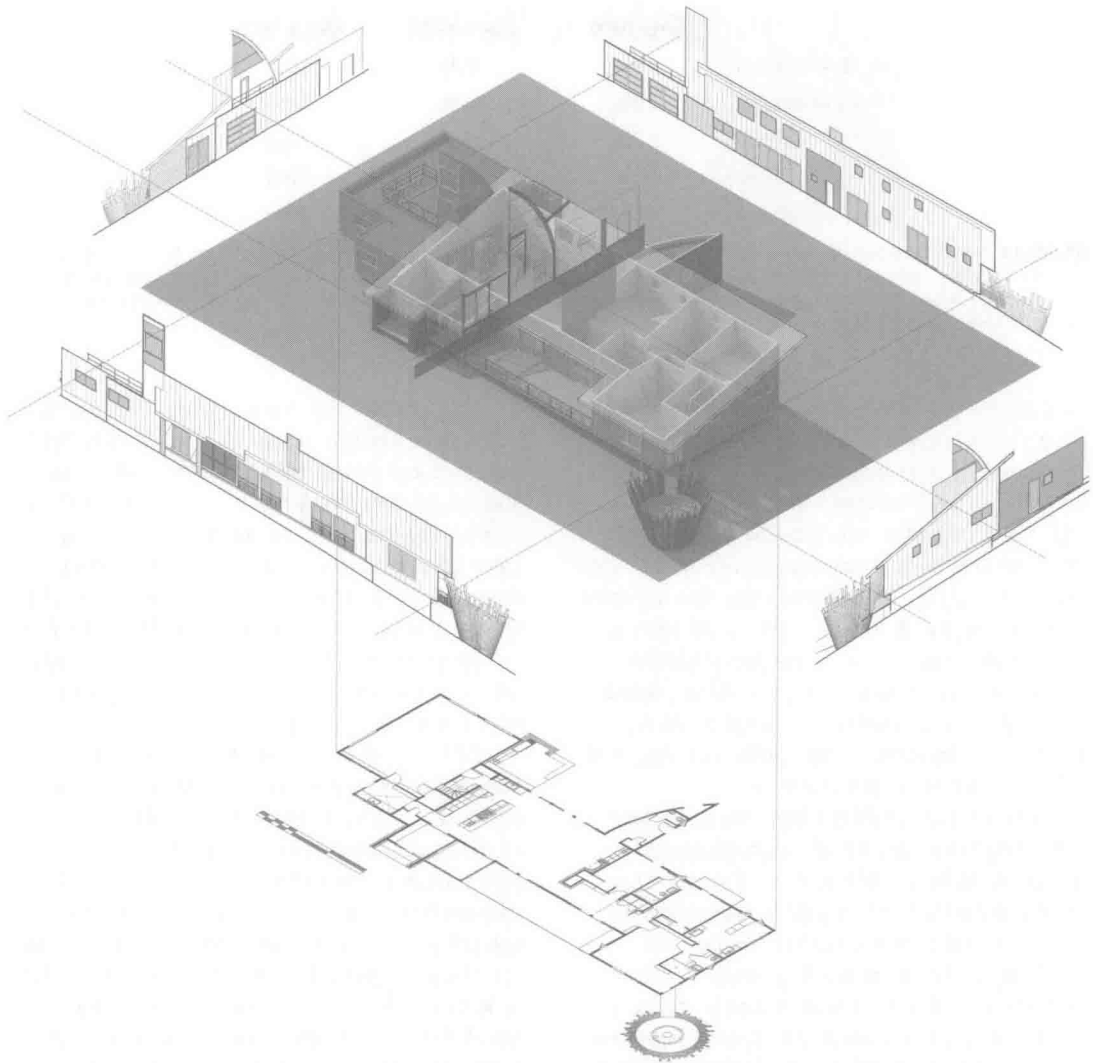


FIGURE 1.2 In traditional construction drawings, a comprehensive “model” of the building is a composite of a variety of 2D views, which are commonly called drawings. If a view is missing, there is a gap in the model.

cost to be for such systems. Specialized projects like laboratories or medical buildings may have as much as 60 percent of construction costs dedicated to mechanical, electrical, and plumbing (MEP) systems (Fig. 1.3). Furthermore, building materials and techniques are by now constantly and rapidly evolving. This, coupled with a tendency to mitigate risk through litigation, has contributed to the trend

toward more extensive, complex, and detailed architectural drawing sets. It is in this technological climate that BIM has emerged.

Defining BIM

Over the last decade, *building information modeling* has gained currency among growing numbers of building professionals and stakeholders, emerging

	pre-1900	since 1970	since 2000
Foundation	15%	15%	15%
Architectural	70%	35%	30%
Structural	15%	15%	15%
HVAC	0%	25%	25%
Electrical	0%	10%	15%

FIGURE 1.3 A greater portion of building cost over time has been dedicated to mechanical and electrical systems. Since structural costs remain somewhat fixed, architectural expenditures have proportionately decreased. These figures are approximated averages based on unpublished research by Steven A. Moore of the University of Texas at Austin School of Architecture in 1999, updated by Dason Whitsett, also of UT SOA.

from arcane obscurity to inescapable buzzword. Developments in building design and analysis software in recent years, coupled with advances in desktop and portable computational power, have engendered effective virtual buildings, or building information models. Gradually, use of BIM is replacing traditional two-dimensional drawing as an architectural design and documentation methodology. Such an approach can increase design efficiencies, foster an integrated design workflow, speed construction documentation and reduce errors, improve building construction and scheduling, and optimize operational performance.

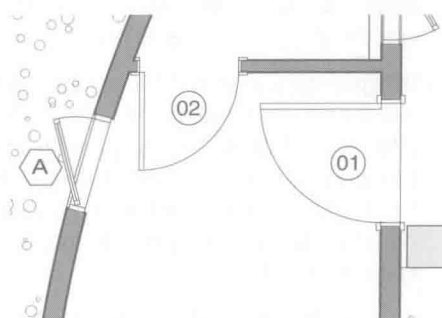
Along the way, BIM has been variously defined, according to the user's profession, perspective, or agenda. In their *BIM Handbook*, Eastman et al. (2008) define BIM as "a modeling technology and associated set of processes to produce, communicate, and analyze building models." They go on to distinguish building models as possessing contextual data-rich building components, whose data are consistent and non-redundant, and have coordinated views. While it is beyond the scope of this book to frame an exhaustive debate of BIM that will satisfy all practitioners, it's essential to clearly define the term in the context of sustainable design for small projects.

Building information modeling: an architectural software environment in which graphic and tabular views are extracted from data-rich building models composed of intelligent, contextual building objects.

Thus, a BIM column is not merely depicted as a two-dimensional drawing or a three-dimensional extrusion, but as an intelligent object that "knows" that it is a column. As a result, various design disciplines can extract and manipulate relevant graphical or tabular building views. *Views* does not mean drawings only (in the form of plans, elevations, sections, isometrics, and perspectives). The term also includes reports: door, window, fixture, and finish schedules, for example, as well as various performance reports (Fig. 1.4).

BIM is a substantial departure from the traditional design methodology that architects have followed for millennia, thanks to both 3D digital modeling capabilities and the critical feature of view extraction. Heretofore, designers constructed multiple 2D drawings that, when viewed together, composed an implicit 3D representation of the building being designed. With BIM, the intelligent model is developed first, and drawings (views) are the result. This not only offers opportunities for greater production efficiencies, but also helps assure greater coordination between deliverables (again, drawings, schedules, and reports) and avoidance of conflicts and collisions. On the other hand, this methodology is to a large extent an inversion of the traditional workflow, with its emphasis on designing by drawing.

Of critical interest to designers is the opportunity to spend relatively more time on design, design more effectively, and capitalize on performance feedback from the virtual building to design for greater sustainability. Patrick MacLeamy, CEO of HOK, is credited with popularizing this graph



Door Schedule

Key	Width	Height	R.O. Width	R.O. Height	Operation	Leaf	Thickness	Manufact
01	2'10 1/4"	7'10 1/2"	3'1 3/8"	8'0"	Swing Simple	Glass	1 3/4"	Marvin Inte
02	2'4"	6'8"	2'6"	6'9"	Swing Simple	Panel	1 3/8"	Supado
03	2'0"	6'8"	2'2"	6'9"	Swing Simple	Panel	1 3/8"	Supado

FIGURE 1.4 A BIM object resides in a relational database, and is subject to a variety of views. In this case, the same door object can be viewed in plan with or without its identifier key, in an elevation, or in a door schedule. None of these is any more the “real” door than any other, and all are editable. Changes to one view affect all other views.

comparing the design team's diminishing ability to control project costs and the increasing cost of making design changes over time, against the traditional architectural fee allocation (Fig. 1.5). Initially intended as an argument for integrated project delivery (IPD), the concept is equally applicable to BIM and sustainable design.

BIM among building professionals

BIM has a broad appeal to a wide variety of building professions throughout the planning, design, bidding and procurement, fabrication, construction, and operation phases of buildings. For many large projects, sophisticated building owners drive the adoption of BIM, perceiving it as an opportunity to reap greater value from Instruments of Service. In such cases, the owner may be motivated by opportunities for faster design and documentation

processes with the expectation of fewer errors, in addition to the benefits of coordinated, interoperable documentation for building operations.

Large construction firms also have been aggressively adopting BIM, finding benefits in faster and more accurate quantity surveying and cost estimating, a reduction in errors through improved 3D collision or clash detection, and more efficient construction scheduling thanks to 4D (sequence) modeling. Anecdotally, it seems to be commonplace for such builders to have in-house staff, who are often recent architecture school graduates and intern architects, to rebuild the architect's CAD or BIM design documentation.

Architects, however, have met BIM with a certain degree of skepticism:

- Who pays for more service? There is the perception that with BIM the architect is providing