Implementing BIM: A Report from the Field on Issues and Strategies

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As Building Information Modeling becomes standardized in the design and construction industries, it is essential to understand concerns and questions surrounding BIM that affect both present and future practice, as well as construction quality.

Business as Usual—Almost

A prior paper, "Building Information Modeling: A Great Idea in Conflict with Traditional Concepts of Insurance, Liability and Professional Responsibility,"[1] explored the gap between an emerging technology, building information modeling (BIM)[2], and the legal and commercial structures that supported—and sometimes undermined—its use. In the intervening years, much has changed. Most notably, public[3] and private owners[4] are now requiring BIM, and it has been widely adopted by designers, contractors, specialty contractors, and fabricators. Studies by Stanford University's Center for Integrated Facility Engineering report that BIM use has risen significantly and will continue to rise in the near future.[5] And between 2006 and 2007, the number of licensed seats of Autodesk's flagship BIM product, Revit, doubled from 100,000 to 200,000.[6] Moreover, by Spring of 2008, McGraw–Hill estimates that the tipping point was reached, as more teams are using BIM than exploring it.[7] This explosive growth has been supported by preliminary development of BIM standards[8] and of related issues, such as electronic data licensing and file transfer.[9] BIM is not tomorrow's vision; it is today's reality.

But many of the issues foreshadowed in the prior paper remain unresolved, albeit better understood and developed. This paper explores these issues and how they affect current BIM use. The paper also addresses practical issues in current BIM implementation and discusses questions construction lawyers

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should ask as they assist clients with their use of BIM. Additionally, because BIM cannot be considered in the abstract, the paper will discuss developments in Integrated Project Delivery that are intertwined with BIM use.

Current Legal Issues Affecting Building Information Modeling

Standard of Care

BIM can affect the standard of care in several ways. At the most basic level, is it below the standard of care to not use BIM if using BIM can readily solve design issues that resist solution when attacked with traditional tools? Clash detection of complex structures is an obvious example.

Historically, designs were developed to a nearly complete level with details omitted to be completed by the contractor from the final, but "diagrammatic" design. In part, this practice was justified because the designer did not know which specific systems would be chosen by the contractor. In other cases, the final layouts were deemed part of the contractor's means and methods and, therefore, not the designer's concern. Because the design was not complete when issued, coordination was often overlooked. More often than one would like, this resulted in designs that could not be coordinated by the contractor or, if it could eventually be coordinated, had a layout that was inefficient and expensive. Many delay and impact claims are born from this coordination problem.

These coordination problems can be nearly eliminated if BIM is used. BIM allows the designer, the contractor and the subcontractors to dimensionally check their respective work and assure that physical conflicts do not occur. Clash reports can be run automatically in the BIM software or multiple models can be imported into a common viewer, such as Autodesk/NavisWorks JetStream.[10] Physical conflict issues can be eliminated during the design phase and confirmed with electronic submittals. Given the expense and disruption caused by clashes discovered during construction, and the ease with which this problem is solved, does the standard of care *require* that the designer use tools that eliminate this costly problem? In the author's opinion, traditionally coordinated two-dimensional drawings are no longer sufficient for complex structures, particularly those with significant mechanical, electrical, and plumbing systems.[11]

BIM also permits rapid comparison of alternatives with iterative improvements in cost, energy utilization and sustainability. As noted in a recent ASHRAE report, sustainability goals require the use of BIM and collaborative project methodologies. Where sustainability is a goal—and it is in many projects today—can traditional approaches be justified?

There are also standard of care issues arising from *how* BIM is implemented. Although it is convenient to discuss *the* model used for a project, in practice project design is an amalgamation of interlocking models created by different project participants. These federated models must be able to exchange information accurately—which requires forethought and discussion between participants. In addition, the designer needs to determine the model's granularity, i.e., the detail to which information is depicted, as this affects the interface between the designer's and the implementer's responsibilities.

Similarly, the designer needs to determine what information will reside in the model and what information will reside in specifications or two-dimensional CAD drawings.

Software is not perfect, and residual flaws will remain despite strenuous debugging efforts. Luckily, these bugs are more often annoying than they are harmful. Sometimes. However, this is not always the case. In *M. A. Mortenson Co., Inc. v. Timberline Software Corp.*,[12] a contractor's bid was $1,950,000 too low because of a software error. In affirming the software vendors motion for summary judgment, the Washington Supreme Court held that the software warranty contained in the instruction manual was incorporated into the purchase contract and that its limitation to the purchase price was valid and not unconscionable.[13] Thus, if errors in BIM software cause economic loss to the user, the injured party has no realistic remedy. But the user's liability to other parties injured by the software error is not similarly limited, causing a liability gap between the software vendor's limited warranty and the designer's responsibility to produce plans or other deliverables in accordance with the standard of care.

Design Delegation and Professional Responsibility

Our tri-partite division between design, construction, and ownership places the architect and engineer as master of the design with responsibility to safeguard the public against unsafe structures. To achieve this public policy, the appropriate design professional must sign and seal the construction documents to signify responsibility for the design. Moreover, the statutes and regulations require the designer to be "in responsible charge." California Business and Professions Code sections 6703 and 5535.1 are typical examples of this statutory requirement.

> The phrase "responsible charge of work" means the independent control and direction, by the use of initiative, skill, and independent judgment, of the investigation or design of professional engineering work or the direct engineering control of such projects.
>
> The phrase does not refer to the concept of financial liability.[14]
>
> The phrase "responsible control" means that amount of control over the content of technical submissions during their preparation that is ordinarily exercised by architects applying the required professional standard of care.[15]

The concept of responsible charge requires that work be performed by the licensed professional or under his or her supervision. But in a BIM world, there is a gray intersection between work performed by the design professional, work performed by the software, and work performed by unlicensed professionals.

First, the technology can perform certain design work historically performed by design professionals. Structural design and detailing software, for example, is capable of modifying the connection details in response to design changes, such as the length of a beam. This occurs without input from the design professional and in response to an algorithm that the design professional did not develop and may not even understand.

Second, the ability to exchange data between models, and to collaborate through the models, creates the possible—and perhaps desirable—result that design details created by subcontractors and vendors will be incorporated into the model and the final construction documents.[16]

These issues are not entirely new. For years, engineers have relied on analysis programs using programming code the engineers have never seen, and might not be able to understand.[17] Similarly, some portion of design has always existed in the coordination drawings, shop drawings, and submittals issued by the contractor and its sub-contractors. But with BIM, what were ancillary or supporting documents are now part of the model, and possibly the contract documents themselves. The gap between statutory requirements and good professional practice is widening. Statutory definitions of responsible charge are out of step with the emerging practice and must be modified to support design collaboration while preserving public safety and confidence.

The converse of professional responsibility is whether activities by the software are the unlicensed practice of architecture or engineering. A recent case decided in a different context highlights the licensing issue. In *Frankfort Digital Servs. v. Kistler*,[18] an individual used bankruptcy software to prepare his Chapter 7 bankruptcy. The software, which was not designed by a lawyer, was an "expert system" that provided advice about filing options and "knew the law" as respects various jurisdictions. A series of adversary proceedings were initiated against the software provider, and using California law, the Ninth Circuit held:

> Frankfort's system touted its offering of legal advice and projected an aura of expertise concerning bankruptcy petitions; and, in that context, it offered personalized—albeit automated—counsel. Cf. Landlords Prof'l Servs., 215 Cal. App. 3d at 1609. We find that because this was the conduct of a non-attorney, it constituted the unauthorized practice of law.[19]

Design and detailing software also "knows" about construction regulations, such as building codes. Moreover, they contain the specialized knowledge of engineering principles that is beyond the ken of laymen. From a legal perspective, there is little difference between Frankfort's bankruptcy software and advanced BIM tools. There is a difference in use, however. In most instances, BIM design software is used by licensed professionals, rather than a lay individual, as in *Frankfort*. But if the design changes are not under the responsible charge of a licensed professional, this distinction is diminished.

Intellectual Property

The fluid nature of the "model" concept creates new intellectual property issues: what is the design, where is the design, and who owns it? As noted previously, current design practice uses a set of interlocking models with a primary model controlling basic geometry enhanced by subsidiary design and fabrication models. These models can be supported, or interact with, external analysis models, cost models, and scheduling software. In a very real sense, the design is the dynamic whole of these parts.

But if this is true, who owns this dynamic design? The theoretical answer delves deeply into intellectual property concepts of joint efforts, derivative works, and work for hire. The practical answer lies in well drafted contract documents that pre-determine who will own specific parts of the model and which parts will be licensed for use.[20]

The locus of the design also creates issues. Because the design may physically reside on multiple servers in multiple locations, and parts or all of the design may exist outside the project jurisdiction, the ability to protect intellectual property may be decided under foreign law. And as discussed below, insuring a dispersed design may also test the limits of coverage.

Insurability

BIM raises property and liability insurance issues. The property insurance issues relate to who has rights in the model(s) (and hence has an insurable interest), and where the model(s) exist(s). This is clearly an area where the insurance industry needs to respond, and the author understands that several carriers are issuing an electronic "valuable papers" coverage to complement existing professional liability policies.

The liability issues are simpler. Professional liability policies are clearly broad enough to cover a designer's use of BIM. BIM is part of current professional practice and should not be treated differently than designing with CAD.

The two professional liability insurance provisions most likely to create coverage disputes are joint venture exclusions and means and methods exclusions. The joint venture exclusion could conceivably be applied to claims arising from projects performed under multi-party collaborative contracts if the contracts are poorly drafted. Means and methods exclusions applicable to some policies could apply if the design required or implied a specific, but incorrect, method. In addition, if the design professional is providing software development or web hosting for the project, care should be taken to assure that these services are not outside the professional liability definition of the policy.[21]

Contractors engaged in BIM projects should have contractor's professional liability coverage because their design contributions could conflict with the design exclusion in their commercial general liability policies. Moreover, the contractor's CGL policy will not cover purely economic losses (such as would arise from loss of modeling information), thus it is important that if the general contractor hosts and maintains the model, there be first party coverage for the loss of modeling information that includes economic losses, or that the contractor have a professional style policy broad enough to cover this loss.

Data Translation

The ability to use information for multiple purposes (data repurposing) is a primary benefit of BIM. Data that supports architectural design can be used for structural engineering, cost analysis, sustainable practices, fabrication, and more. Because the industry currently relies on a set of interconnected BIM products and analysis tools, it is vital that information be accurately transferred from one program to another, and in many cases, be accurately returned to the originating program after it has been enhanced elsewhere (round-tripping). This goal is interoperability.

For some purposes, interoperability has been effectively achieved. Geometric information can generally be exported and imported from one program to another without difficulty. However, the additional data describing attributes of design elements may or may not successfully transport or round-trip between programs. Part of the problem may arise because translation conduits have not yet been written. But at a more fundamental level, if two programs have dissimilar features only the common features will be translated. Thus, some information may not survive translation.

Interoperability is a major issue. An often cited National Institute of Standards and Technology study estimates that the annual cost of inadequate interoperability in the United States is $15.6 billion,[22] and a recent McGraw Hill study reports that project participants estimate that lack of adequate interoperability adds 3.1% to total project cost.[23] Moreover, the BIM experts surveyed for this report are most concerned with interoperability.

> BIM has emerged as a critical catalyst in the effort to create interoperability within the building community. However, with all disciplines envisioning a place for BIM, the need for interoperability is heightened as firms invest deeper in its uses. As firms become experts in BIM, they begin to face the limits of its use.[24]

Interoperability is also seen as a critical factor in transitioning to Integrated Project Delivery.

> Interoperability will become more of an issue as we continue to push for the use of new technology, whether it be BIM or any other technology that gets us closer to an integrated project delivery system. Our goal is to be able to develop within the project [build] team an attitude that improves the process by having teams that are fully integrated and cooperative with each other. You need to be able to take advantage of technology that allows the freeflow of information from the submittal stage to the operations and maintenance phase. We see interoperability as a challenge to achieving that.[25]

Although interoperability remains a significant issue, significant progress has been made and standards are continuing to develop. In the United States, the National Institute of Building Science (NIBS) has undertaken the most extensive attempt to define BIM. NIBS released the first version of the National Building Information Modeling Standard (NBIMS) for comment on March 13, 2007 and issued Version 1.0 on December 18, 2007.[26] Its purpose is described as follows:

> The NBIMS will provide the diverse capital facilities industry with a vision of how to support and facilitate communications throughout the facility lifecycle, from project inception through design and construction, even past demolition for improved operations, maintenance, facility management, and long-term sustainability.
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> The document was assembled by over thirty subject matter experts from across the capital facilities industry. It provides both a snapshot of where this burgeoning capability exists today as well as identifies work still needing to be accomplished. This first part of Version 1.0, which is now out for review, will be followed by Part 2 at the end of the year. Part 2 will contain items to be standardized across the industry using the NIBS congressionally authorized consensus process.
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> The NBIMS has six goals: 1) Seek industry wide agreement, 2) Develop an open and shared standard, 3) Facilitate discovery and requirements for sharing information throughout the facility lifecycle, 4) Develop and distribute knowledge that helps share information that is machine readable, 5) Define a minimum BIM, and 6) Provide for information assurance for BIM throughout the facility lifecycle. As an initiative under the Building SMART® Alliance, it is garnering support from the widest

spectrum of associations, agencies, organizations, vendors, and individual practitioners ever assembled.

On a global level, the International Alliance for Interoperability[27] (IAI) facilitates interoperability by defining Industry Foundation Classes[28] as a uniform basis for collaborative information use and exchange. IAI currently has more than 400 members in 24 countries and is the leading interoperability organization.[29] In North America, the IAI functions as a council of the National Institute of Building Sciences.[30]

Other solutions are being developed to facilitate interoperability. In addition to supporting IAI standards, Autodesk's Revit BIM systems are available in discipline optimized versions that use a common engine to permit tight integration between the related models. Other software producers also have links between their programs and related products.

Miscommunication and misunderstanding can lead to loss and liability. To reduce potential liability, digital data transfer agreements replete with liability waivers and caveats regarding use have become common.[31] At their extreme, these documents prohibited reliance on the electronic documents and require that the receiving party compare the digital information against hard copy documentation. But prohibiting reliance undermines the signal advantage of digital information: its ability to be efficiently exchanged and repurposed. Thus, current practice is evolving to allow reliance on transferred data for specifically identified uses.

In 2007, The American Institute of Architects created a digital transfer document that does not have any substantive caveats.[32] The recipient has the right to use the information for the specific project in one of four ways:

- Store and view;
- Reproduce and distribute;
- Integrate (incorporate additional digital data without modifying data received); and
- Modify as required to fulfill obligations of the Project.[33]

But provided the recipient uses the information for the project and in accordance with the rights granted, it can rely on the accuracy of the information. This modern approach requires that both parties understand the needs of the other and any limits on effective interoperability.

Data Adequacy

Even if data is transferred accurately, issues can be caused by differing needs of transmitter and recipient. Tolerances are a significant issue. For example, the tolerances necessary for analyzing a steel frame structure (structural engineer's interest) are different from those required to construct the steel frame (fabricator/erector's interest), which are different from those required for the curtain wall system (manufacturer's interest). Data currency requirements (whether information is up-to-date), also differ between project participants. Just as with data translation, it is important for persons transmitting and receiving data to understand and agree on acceptable tolerances and currency.

Privity, Third Party Reliance, and the Economic Loss Doctrine

Design professionals have long sought to distance themselves from economic disputes between the contractor and the owner. Where the contractor asserts direct claims, designers have argued that they are not liable because they aren't in privity with the contractor and that the damages sought are not recoverable due to the economic loss doctrine. These arguments have been partially successful, although the scope and exceptions to the economic loss doctrine varies between jurisdictions.[34]

But if information is provided for another's reliance, privity is not necessary to recover economic damages. The essentials of a negligent misrepresentation claim are set forth in RESTATEMENT (SECOND) OF TORTS § 552 as follows:

> (1) One who, in the course of his business, profession or employment, or in any other transaction in which he has a pecuniary interest, supplies false information for the guidance of others in their business transactions, is subject to liability for pecuniary loss caused to them by their justifiable reliance upon the information, if he fails to exercise reasonable care or competence in obtaining or communicating the information.
>
> (2) Except as stated in Subsection (3), the liability stated in Subsection (1) is limited to loss suffered:
>
>> (a) by the person or one of a limited group of persons for whose benefit and guidance he intends to supply the information or knows that the recipient intends to supply it; and
>>
>> (b) through reliance upon it in a transaction that he intends the information to influence or knows that the recipient so intends or in a substantially similar transaction.
>
> (3) The liability of one who is under a public duty to give the information extends to loss suffered by any of the class of persons for whose benefit the duty is created, in any of the transactions in which it is intended to protect them.[35]

From the prior discussion of data transfer and interoperability, it should be plainly understood that an acknowledged data recipient can state a claim under §552 and that privity and the economic loss doctrine will have little sway.

Although these defenses are diminished, risk is not necessarily increased. The ability to share model information between designer and contractor leads to better quality documents and the avoidance of physical clashes.[36] Thus, designers increase their exposure by providing information but, by reducing the probability and severity of project failure, can effectively reduce their risk.

Spearin Implied Warranties

The *Spearin* doctrine, introduced by the Supreme Court in 1918, allocated defected design risk by implying an owner's warranty that plans are complete and accurate. The *Spearin* court found that "the one who provides the plans and specification for a construction project warrants that those plans and specifications are free from defect."[37] Although initially a defensive doctrine, *Spearin* has evolved into an offensive weapon that permits contractors to recover whenever plans have errors or omissions,[38] which is almost certain to occur in any real project.

In principle, *Spearin* does not affect design professionals because the implied warranty is solely from owner to contractor. In practice, however, it overshadows much of construction litigation because in any delay and impact claim it encourages the contractor to allege design deficiencies that will trigger the absolute *Spearin* warranty. Caught between the contractor and the designer, many owners believe they must cross-claim against the design professional to protect against inconsistent verdicts and less scrupulous owners view the design professional as a funding source for resolving the contractor's claim.

The *Spearin* doctrine does not apply to performance specifications because the owner has not dictated how the work will be performed.[39] Thus, the characterization as "design" or "performance" specifications determines the existence of the implied warranty—and often the result.[40] Specifications containing performance and prescriptive elements (hybrid specifications) result in differing outcomes because it is difficult to determine the essential character of specifications.

> . . .[T]he distinction between design specifications and performance specifications [are] not always clear, and many specifications are hybrids. The general consensus of authority in the conventional design-bid-build context is that, where the owner designates particular components, dimensions, material types or qualities, or other details, the owner impolitely warrants those details. [cit. omit] On the other hand, where the specifications simply set forth the performance characteristics of the end product and leave to the contractor how to achieve those results, no implied warranty is said to arise. [cit. omit] As one commentator has summarized, "liability follows from design responsibility." [cit. omit][41]

If the project design incorporates material information provided by the contractor, there will be no implied warranty.[42] For example, in *Austin v. United States,* a contractor agreed to design, manufacture, test, and deliver an innovative digital data recording system.[43] The contract contained detailed specifications as to the method of constructing the system, but the contractor determined that the contract would be impossible to perform using those specifications.[44] It modified the design, but was still unable to successfully execute the contract.[45] The court denied the contractor the defense of impossibility, finding that because the contractor had integrated his own design into that of the original contract, he warranted his ability to successfully perform those substituted specifications.[46]

In a fully modeled project, particularly in a collaborative project where subcontractor and vendor information is incorporated into the design, it appears that courts would turn to cases of hybrid specifications to determine whether to imply a warranty. This will be a factual inquiry, but the deeper a contractor's involvement in the design, the less likely a warranty will be implied.

The contractor's ability to discover defects (the patent deficiency exception to *Spearin*) is also increased with collaborative BIM. As noted recently:

> First, wholesale implementation of BIM methodology contemplates, if not demands, full participation by the contractor in reviewing the design model early-on in the design process. In such event, the contractor may lose the benefit of the owner's implied warranty by application of the patent defect exception to the Spearin Doctrine which requirement patent errors be recognized. To point out the obvious, BIM participation by the contractor may and could well lead to timely (preconstruction) discovery

> and correction of certain design errors so as to abrogate any subsequent necessity to invoke the Spearin doctrine. Nevertheless, it is a certainty that certain design errors in certain circumstances will not be detected. In such instances, the right of the contractor who participates in BIM to invoke the Spearin Doctrine involves an analysis of whether an error otherwise latent should be considered patent. In that regard, it is not unreasonable to project that the invocation of the Spearin Doctrine by a contractor and BIM participant in such a situation will be set quite high.[47]

Thus, the contractor's involvement in design, which may defeat the designer's economic loss and privity defenses, may also diminish the contractor's implied warranty claims.[48]

Implementing Building Information Modeling

Implementing BIM within a design or construction organization requires commitment to developing new workflows and competencies. Implementing BIM on a project requires planning and consideration of the following issues. Attorneys assisting their clients should assure that these issues are considered at the project's inception.

How Will the Model(s) be Used?

The level of information in the model(s) and the protocols for their use and management will depend upon how the model(s) will be used. Thus, the participants should outline the planned uses to allow all parties to understand how they should create and manage their data. Possible uses to consider are:

- Solely for design;
- For coordination and clash detection;
- For estimating material quantities;
- For continuous cost estimating in support of target value design;
- For structural, wind or other analyses;
- For energy use, light studies, sustainability, or other optimizations;
- For construction simulation (construction rehearsal);
- For creation of shop or fabrication drawings;
- For review of submittals;
- For support of LEED submittals;
- For agency review; and
- For facility management.

Who Will Own and/or License the Model(s)?

In most instances, it does not matter who owns the model as long as all parties have sufficient licensed rights to use the model(s) for project purposes. However, it is important that the issue be settled because ownership of jointly created works can be troublesome. There are three primary options, all of which are workable provided the details are correctly handled in the contract documents.

1. Owner Owns Modeling Information.

This option will be preferred by many institutional and public owners because they typically own information created for them, such as contract documents. Under this option, all of the project participants must be licensed to use the modeling information for project purposes. Design professionals, at least, will also want the right to display their designs for promotional or educational purposes and may want the right to reuse elements created for the project.

The "owner owns" approach also raises the issue of what information in the model should be transferred to the owner. BIM software contains a modest amount of predefined elements that can be aggregated into a design. But designers will extend this palette by developing their own standard library of elements and will develop custom elements for use with a specific design. These elements are portable and reusable, much like architectural detail libraries. Even if the owner obtains title to the design model, designers should reserve ownership of their standard library elements so they can reuse their standard elements on later projects. In addition, designers should be indemnified against liability arising from later modifications and reuse of the model(s).

2. Designer Owns Modeling Information

This option is consistent with traditional AIA contract documents that define designs as the architect's instruments of service, and for that reason, may be preferred by some. The owner, the contractor, and others who need to use the information would be licensed to use the information by appropriate language in the designer's agreement. The owner's license needs to include the ability to use the modeling information for operation and maintenance, including revisions to the project. Because the owner's license will include limited reuse, the designer should be indemnified against liability arising from subsequent modifications and reuse.

3. All Parties Own Whatever They Create

Although this approach sounds simple, it requires cross-licensing between all parties and, thus, provisions in all of the principal contracts. Other than this additional complication, it is similar to the designer owning the modeling information.

Finally, the project insurance program should assure that the modeling information, whichever party owns it, is insured for the respective interests of the parties.

What is the Model's Contractual Status?

This question raises practical and legal issues. First, what is the scope of the contractually significant model? As noted previously, projects are built from a series of interrelated models rather than a single, global model. Beyond the primary design model, there may be mechanical design models, structural design models, structural fabrication models, mechanical fabrication models, analysis models and possibly others. Is associated cost and schedule information part of the model? Before contractual status is conferred, the parties should determine what is, and isn't, contained in the contractual model.[49]

Second, under current practice portions of the design will not be modeled. Standard details, for example, are often provided as two dimensional drawings because they have not been converted to modeled forms. Information that must be more precise than supported in the model will also be provided as traditional CAD drawings. Similarly, topographical, civil and landscaping information may be conventionally drawn. Finally, specifications will likely exist outside of the building information model(s). Thus, the complete design will be an amalgam of modeled and unmodeled information.

When building information models first appeared, they were denied contractual status. The hardcopy drawings printed from the model, together with the additional traditional prints, were the only contract documents. But flattening the model into printed sheets sacrifices the three-dimensional information and the additional information associated with the model and its elements. To avoid this result, more current practice considers the model one of the contract documents.[50]

But if the model is only one of the contract documents, inconsistencies may arise between two dimensional and modeled information. The order of precedence depends upon project specifics, but in general, because the model is fully coordinated and dimensionally accurate, it should be the primary dimensional control.

How Will Modeling Requirements be Specified?

As anyone who has reviewed a comprehensive CAD standard can attest, it is possible to specify drawing standards to a very fine degree. In theory, it should be possible to similarly create a prescriptive BIM standard. In practice, however, this is difficult to accomplish.

Unlike current CAD projects, modeled projects use a variety of different, interacting, BIM software. Although the project documents may specify the primary BIM products, the subsidiary applications may not be determined until after contracts have been signed. Moreover, the depth to which a project is modeled and the scope of the model(s) use can vary from project to project. In addition, a participant's experience with modeling varies, and many owners (and specification writers) are neither fully aware of the possible options, nor capable of defining what they need. At present, modeling requirements are rarely as detailed as a companion CAD standard.

Instead of a detailed standard, either a performance or hybrid specification can be used. Performance specifications state the goal of BIM use without specifying how it will be accomplished. For example, the specification could state, among other things, that the model will be used for costing as well as design, will be provided to specialty contractors as a basis for their fabrication or shop drawings, and will be used to review and approve shop drawings and submittals. By defining the use, contracting parties are told who will be relying on information and for what purpose and can accordingly adjust their expectations and practices. But a performance specification will not provide the detail necessary to assure fluid and reliable communication or provide the drawing standards that the project team will need. Thus, if a performance approach is used, it should be supplemented by a post-contract BIM workshop where the parties meet to develop standards and protocols for their specific products, on that specific project, in order to meet the project goals.

A hybrid approach may also be used. In a hybrid specification, detail is provided regarding the types of allowable software, requirements for interoperability, depth of modeling and similar details, but the participants must augment these standards and protocols after the project has commenced. This hybrid approach is currently being used by the United States Army Corps of Engineers[51] and others.[52]

How Will the Model be Administered?

Model administration is comprised of three primary tasks that may or may not be performed be a single entity. First, the model needs to be hosted securely and reliably. This is an information technology task. Second, the model needs to be kept current with appropriate versioning and audit trails. Rights to access specific project areas need to be granted, audited, and enforced. This is an administrative task. Finally, the authority to substantively change modeling information needs to be vested in the entity competent and professionally responsible for the content. This is a professional task.

The first two tasks can be assigned to any party. Models can, and are, hosted by the prime designer, the contractor, the owner, and by third-party consultants retained by the owner. This is a task that should be undertaken by the entity best capable of providing a secure and stable system. The administrative task can, again, be provided by the party most capable. A knowledgeable construction or program manager might be a logical choice because they routinely manage and facilitate information flow.

The professional task, however, must remain with the professionals responsible for specific aspects of the design. The structural system, for example, cannot be modified without the concurrence of the structural engineer. The building layout and base geometry cannot be modified without the concurrence of the architect. Thus, the BIM protocols should specify who will handle the hosting and administrative chores, but must define who has authority and responsibility for substantive content.

Taking BIM to the Next Level: Integrated Project Delivery

Building Information Modeling does not require a collaborative process. Designers can use the existing software to prepare traditional plans and specifications without providing the digital model to the contractor, its subcontractors and suppliers, or even to the owner, itself. Contractors can create models for estimating, fabricating or construction simulation without ever sharing the information. But doing so wastes the power of Building Information Modeling as a collaborative framework and discards the cost and quality advantages of single entry, multiple use. Moreover, an insular approach ignores current best practices favoring Integrated Project Delivery with Building Information Modeling at its core.

The Need for Integrated Project Delivery

The construction industry has long been plagued by fragmented and fractious project delivery processes. Competitive low bid procurement, guaranteed maximum price and similar contract structures have fostered an individualistic, zero-sum approach to construction. These processes, in conjunction with other influences, have resulted in declining labor productivity. According to research by Dr. Paul Teicholz at the Stanford University Department of Civil & Environmental Engineering, construction labor productivity has declined by approximately 20% between 1964 and 2004, whereas industrial productivity has increased approximately 200% during the same period.[53] Estimates of waste in construction are similarly alarming. The Construction Industry Institute estimates that 57% of all construction activity does not add value.[54] An earlier study concluded that 30% of project costs were wasted because of mismanagement caused by the division between design and construction.[55] Owners are understandably concerned and the Construction Users Roundtable (CURT), a leading construction owner organization, has concluded that wholesale industry change is necessary to achieve successful projects.[56]

After analyzing the causes of declining productivity, CURT issued a policy report mandating integrated project delivery methodologies.[57] The report proposed four elements of a new policy framework.

> *Owner Leadership:* Owners, as the integrating influence in the building process, must engage in and demand that collaborative teams openly share information and use appropriate technology. CURT should establish policy and procedures to implement change in the AEC industry and encourage other building owner organizations to join the effort.
>
> *Integrated Project Structure:* The building process cannot be optimized without full collaboration among all members of the design/build/own project. CURT and other owner organizations should establish policies that support such collaboration.
>
> *Open Information Sharing:* Project collaboration must be characterized by open, timely, and reliable information sharing. CURT should advocate the establishment of procedures and protocols to achieve this end.
>
> *Virtual Building Models:* Effectively designed and deployed information technology will support full collaboration and information sharing and will lead to more effective design/build/manage process. CURT should endorse establishing technology-based lifecycles that optimize the creation, interaction, and transport of digital information throughout the building process.

CURT's vision of an integrated project built around virtual building information models was sharpened in a later report on implementing the optimized building process.

> *Technology/Building Information Modeling*
>
> Desire for re-use of project information beyond the building design created by architects and engineers will drive market adoption of building information models. Standards will be established for how building information models are developed with regard to content and modeling methods to produce information supporting downstream BIM automation services that are aligned with the owner's business objectives. Ultimately, for BIM to succeed, owners must acknowledge that all risk comes from them and ultimately returns to them.
>
> Owners must set the tone for the project by requiring their design and construction teams to use the latest technologies. Including these

requirements in requests for proposals is one simple step that owners can start using. Further, the owner should use the technology as well.

Owners should support industry initiatives to create standards where they are needed. Owners should also increase their awareness of the technology tools their consultants and contractors are using on their projects. Owners must recognize that the choice of technology solutions will affect their projects, not just during the development phase, but also after the project is completed and operating.[58]

Information Sharing

An essential element woven throughout the vision of transformation to an optimized model is the ability for all parties to communicate freely. Current practices of silence for fear of liability must be eliminated and a new process where decisions are made at the highest and most appropriate level of competency must be established to leverage team knowledge. … This issue most certainly is the greatest obstacle to transformation and the realization of the optimized project. Owners must demand this openness and transparency from the team entity of which they are a part.[59]

CURT's message is quite clear. Projects should capitalize on the competencies of all project participants and must promote open communication using the best technologies available. Building Information Models should be at the core of the process. Although the CURT reports called for change, they did not explain how to create the radical transformation required.

The Development of Integrated Project Delivery

In June of 2007, the American Institute of Architects California Counsel in partnership with McGraw Hill issued *Integrated Project Delivery: A Working Definition*.[60] This document set forth the fundamental assumptions and framework for a fully integrated project. These include early involvement by all key participants, compensation and risk tied to project, not individual success, open communication between all participants and collaborative decision making. The *Working Definition* directly responded to CURT's call to action. The concepts in the W*orking Definition* were further developed by a joint American institute of Architects[61] and AIACC task force and published on November 5, 2007 in *Integrated Project Delivery: A Guide*.[62] As defined in the Guide:

Integrated Project Delivery (IPD) is a project delivery approach that integrates people, systems, business structures and practices into a process that collaboratively harnesses the talents and insights of all participants to optimize project results, increase value to the owner, reduce waste, and maximize efficiency through all phases of design, fabrication, and construction.

The *Guide* provides the fundamental principals to IPD, a road map for its implementation, and the outline for alternative legal and business models supporting IPD. Both the *Working Definition* and the *Guide* recognized that the technology of BIM was intertwined with the process of IPD.

A Note on Building Information Modeling

It is understood that integrated project delivery and building information modeling (BIM) are different concepts—the first is a process and the

> second a tool. Certainly integrated projects are done without BIM and BIM is used in non-integrated processes. However, the full potential benefits of both IPD and BIM are achieved only when they are used together. Thus, the IPD phase descriptions included here assume the use of BIM.[63]

Similarly, although the Working Definition did not foreclose having an integrated, but unmodeled project, the committee concluded:

> Although it is possible to achieve Integrated Project Delivery without Building Information Modeling, it is the opinion and recommendation of this study that Building Information Modeling is essential to efficiently achieve the collaboration required for Integrated Project Delivery.[64]

In its discussion of IPD implementation, the Guide explicitly recognizes that IPD will be executed through BIM and that BIM provides a framework for collaboration.

> Building Information Modeling (BIM), a digital, three-dimensional model linked to a database of project information, is one of the most powerful tools supporting IPD. Because BIM can combine, among other things, the design, fabrication information, erection instructions, and project management logistics in one database, it provides a platform for collaboration throughout the project's design and construction. Additionally, because the model and database can exist for the life of a building, the owner may use BIM to manage the facility well beyond completion of construction for such purposes as space planning, furnishing, monitoring long term energy performance, maintenance, and remodeling.[65]

Others, particularly the Lean Construction Institute (LCI),[66] have promoted collaborative approaches to design and construction delivery. LCI prepared the first multi-party integrated form contract used in the United States and which formed the basis for the recently introduced ConsensusDocs Series 300 integrated agreement.[67] LCI also supports the use of BIM. And by the time this paper is delivered, the American Institute of Architects will likely have released their standard agreements for integrated project delivery. The evolution of BIM and the development of integrated project delivery will result in an increasing number of fully modeled, fully integrated projects.

The Implications of Integrated Project Delivery

Although IPD projects all share certain common features—early involvement of key contributors, open communication, team decision making, and a sharing of risk and reward based on project success—the legal structures supporting IPD can vary widely. AIA/AIACC's Guide recognizes three primary variants: relational agreements, single purpose entities, and alliance/alliance like agreements. Even within these categorizations, there are individual variations and hybrids. An accurate assessment of legal implications requires examination of the specific approach used.

One of the first implications of IPD is an increase in process cost. Most of the IPD approaches require intensive team formation and process design phases. In IPD, the parties are creating a virtual organization for project execution and it takes time and effort to determine how the individual participants will fit into and interact in this project team. This initial process design phase is also a period where the parties begin to build the bonds of trust they will need during the project. The increased process cost will be recaptured through greater project efficiency—provided the project is of sufficient size.[68]

The second implication is a shift from fault based liability allocation to allocation based on project outcome. In most IPD scenarios, project outcome risks (budget, schedule, & quality) are allocated through compensation incentives. If a project overruns its targets, the non-owner parties' profits are reduced or eliminated. If the project exceeds expectations, the non-owner parties' profits increase. This project risk sharing supplants traditional intramural liability assessments and is reflected by liability waivers or limitations among the project participants. Because litigation between owner, contractor and designer are the most common and costly forms of construction litigation, the reduction of these intramural claims greatly reduces the parties' risk.

Because IPD is collaborative at its core, the economic loss doctrine, third party reliance, and privity issues defenses discussed previously are largely ineffective. Similarly, the *Spearin* warranties are diminished or eliminated. But because risk and liability have been allocated by contract, the importance of these concepts is diminished. Liability to third parties is not significantly altered in an integrated project and the parties rely on project or individual insurance to protect against this risk.

A third implication is a change in work and cash flow. In an IPD project, the most intensity design period (detailed design using the AIA/AIACC parlance) occurs earlier in the project. This, along with the process design effort, will shift the timing of design costs, even though the total design cost will not necessarily increase. In addition, because work is assigned on a "best person" basis, some of the work done by designers in the traditional construction documents phase will be supplanted by detailed design performed by contractors and vendors. Designers should recognize that they are selling creativity, not just hours, and will need to adjust their internal business models to reflect this reallocation.[69]

Finally, many of the legal issues discussed in regard to BIM also apply to IPD, but more intensely. For example, the design delegation/professional responsibility issue is heightened by the deeper collaboration between the parties. Who owns the design and similar intellectual property issues are also amplified by IPD. But, the fluid nature of IPD should not justify poor delineation of responsiblities—although that may occur if the parties plunge into IPD without clarifying individual roles. Blurring of roles affects insurance coverage if work bridges between entities. Eventually, we may see omnibus insurance products designed for IPD, but presently, care must be taken to assure that the parties are adequately covered using a portfolio of existing products.

IPD, and to a lesser degree BIM itself, can create new exposures for all project participants. But these new exposures are created in an environment that is "self healing." Because risk and reward are jointly shared, the parties are stimulated to solve problems rather than assign blame. Moreover, but involving key contributors at an early stage, many more potential problems will be discovered and resolved long before the occur. Thus, the probability of failure and the magnitude of its consequence diminish even if the avenues for claims are expanded. And to a great degree, the expanded claims potential is reduced or eliminated by the internal liability waivers contained in the IPD agreement.[70]

Conclusion

Building Information Modeling has passed its experimental stage and is now an accepted standard for project design and delivery. On complex projects, such as hospitals, it is now the standard, and using lesser tools is potentially below the standard of care. The industry has already seen significant improvements in project quality and is poised to reap even greater benefits as collaborative project delivery approaches, such as Integrated Project Delivery are executed using BIM as a framework for collaboration. But while moving forward, the industry should work to reduce inconsistencies between existing regulations and developing practice, to increase understanding of this technology's benefits and implications, and to develop project delivery methods that enhance the power of Building Information Modeling.

Endnotes

[1]Schinnerer's 45th Annual Meeting of Invited Attorneys.

[2]Because this paper focuses on developments in Building Information Modeling, it is assumed that the reader knows what Building Information Modeling is and why it is a critical technology in design, construction and facility management. For readers who would like more information on BIM, generally, there is a brief overview as an appendix to this paper.

[3]For example, the General Services Administration, the United States Army Corps of Engineers, and the United States Coast Guard all have BIM requirements.

[4]During the last six months, the author has been involved in developing project documents for 6 hospitals and several major tenant improvement projects. *All* of these projects are being implemented in BIM.

[5]Gilligan and Kunz, *VDC Use in 2007: Significant Value, Dramatic Growth, and Apparent Business Opportunity*, Center for Integrated Facility Engineering, Report TR171 (2007).

[6]Autodesk press releases in 2006 and 2007 reported 100,000 Revit seats sold through June 8, 2006 and over 200,000 seats sold through May 4, 2007.

[7]*Interoperability in the Construction Industry*, McGraw Hill SmartMarket Report (2007) p. 11.

[8]Most notably, the National Institute of Building Science's National Building Information Modeling Standard V. 1.0, **http://www.facilityinformationcouncil.org/bim/publications.php**. As this paper is being written, ConsensusDocs is circulating a draft BIM specification that should be issued in 2008.

[9]See, for example, American Institute of Architects standard documents C-106, *Digital Data Licensing*, E-201 *Digital Data Protocol*, and the ConsensusDOCS Document 200.2, *Electronic Communications Protocol Addendum.*

[10]In theory, clash detection can be done using lighttable overlays. However, they rarely identify all potential clashes. The author has recently learned of a hospital design with fully coordinated 2D drawings that, when converted into a BIM model, were found to contain over 100 significant clashes. Not surprisingly, sophisticated owners of complex facilities are routinely requiring full clash detection in BIM.

[11]The author represented the owner of a university laboratory where a partially diagrammatic design was used for the MEP systems. When the systems were modeled, many conflicts were found supporting the contractor's argument that it had to "redesign" the systems, not merely coordinate them.

[12]140 Wn.2d 568; 998 P.2d 305 (2000).

[13]140 Wn.2d 568, 584-88 (2000).

[14]Cal. Bus. & Prof. Code §6703. There are companion statutes for surveyors (B&P§8703) and geologists. (B&P§7806).

[15]Cal. Bus. & Prof. Code § 5535.1.

[16]This recently occurred in a Northern California hospital where the final mechanical drawings were prepared by the mechanical subcontractor, but stamped by the mechanical engineer (who had worked collaboratively with the subcontractor and could be said to be in responsible charge).

[17]In the early days of the author's litigation practice, engineers would occasionally be required to produce the programming code used to analyze an

engineering problem and explain to a confused court and jury, how the program was constructed and why it was reliable, before introducing the results. This requirement has largely evaporated as analysis software has become commonplace.

[18]477 F.3d 1117 (9th Cir. 2007).

[19]477 F.3d 1117, 1126 (9th Cir. 2007).

[20]Design professionals are often concerned that their additions to a BIM software's library of components will be "adopted" by others who have access to a project model. This is the high tech equivalent of copying a firm's standard details. Although reprehensible, and you can craft contract language to prohibit it, there is no practical way to quell this "borrowing", because enforcing the firm's copyright would require constant vigilance and expensive legal action.

[21]The author has reviewed enhancements to standard professional liability policies that are designed to expand coverage to include IT tasks related to BIM, such as management and hosting of the project model(s). However, these enhancements are not standard and interested design professionals should discuss these issues with their professional liability broker.

[22]Gallaher, O'Connor, Dettbarnm Jr., and Gilday; *Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry*, NIST 2004, pp. 6-1, 6-3.

[23]*Interoperability in the Construction Industry*, McGraw Hill SmartMarket Report (2007) p. 11. Interestingly, architects and engineers estimated a higher impact than contractors.

[24]*Id.*

[25]Ricardo Aparicio, Manager General Electric, President, Construction Users Roundtable.

[26]Version 1.0 of the standard is available at: **http://www.facilityinformationcouncil.org/bim/publications.php**

[27]**www.iai-international.org**

[28]IFCs are an object oriented, open source, data format for specifying elements in a BIM. A BIM that utilizes IFCs should create data files that can be read and manipulated by other IFC compatible software. The primary BIM vendors, such as Autodesk, Graphisoft, and Bentley (as well as others) support the IFC standards.

[29]Many of the primary BIM platforms support the IFC standards. For example, Bentley Architecture (**www.bentley.com**), ArchiCad (**www.graphisoft.com**) and Revit (**www.autodesk.com**) are fully or partly IFC compliant.

[30]**www.iai-na.org**

[31]EJCDC Doc. C700 contains a defensive digital transfer document. It states:

> §3.06 Electronic Data
>
> A. Unless otherwise stated in the Supplementary Conditions, copies of data furnished by Owner or Engineer to Contractor or Contractor to Owner or Engineer that may be relied upon are limited to the printed copies (also known as hard copies). Files in electronic media format of text, data, graphics, or other types are furnished only for the convenience of the receiving party. Any conclusion or information obtained or derived from such electronic files will be at the user's sole risk. If there is a discrepancy between the electronic files and the hard copies, the hard copies govern.
>
> B. Because data stored in electronic media format can deteriorate or be modified inadvertently or otherwise without authorization of the data's creator, the party receiving electronic files agrees that it will perform

acceptance tests or procedures within 60 days, after which the receiving party shall be deemed to have accepted the data thus transferred. Any errors detected within the 60-day acceptance period will be corrected by the transferring party.

C. When transferring documents in electronic media format, the transferring party makes no representations as to long term compatibility, usability, or readability of documents resulting from the use of software application packages, operating systems, or computer hardware differing from those used by the data's creator.

[32]AIA Document E201 (2007). The document does contain a warranty that the transmitting party is the owner of the data or has the right to transmit the data to the recipient. (§2.1)

[33]AIA Document E201 (2007) Project Protocol Table, §3.2.

[34]For an excellent summary of the economic loss doctrine in construction cases, see, Andrus, Gessford & Joyce, *The Economic Loss Doctrine in Construction Cases: Are the Odds for Design Professionals Better in Vegas?*, J ACCL, Winter 2008, p. 53.

[35]RESTATEMENT(SECOND) OF TORTS, §552.

[36]During private discussions with a major supplier of electronic plan management services, the author was told that the service provider has seen a significant reduction in addenda if building information modeling is used. This is an indication that BIM produced plans are more consistent and complete.

[37]*United States v. Spearin* (1918) 248 U.S. 132.

[38]See, e.g., *Hercules Inc. v. United States* (1994) 24 F.3d 188, 197.

[39]*Stuyvesant v. United States* (1987) 834 F.2d 1576, 1582; White v. Edsall Const.Co. Inc., 296 F.3d 1081, 1085. (Fed. Cir. 2002)

[40]For a criticism of the design/performance litmus test, see, *The Spearin Doctrine: The False Dichotomy Between Design and Performance Specifications*, 25 Pub. Con. L.J. 47 (1995).

[41]Hamersmith & Lozowicki, *Can the Spearin Doctrine Survive in a Design-Build World: Who Bears Responsibility for Hybrid Specifications*, J. ACCL Winter 2008, 123, 129.

[42]Austin Co., 314 F.2d at 520.

[43]*Id.* at 519.

[44]*Id.*

[45]*Id.*

[46]*Id.* at 520.

[47]O'Brien, T., *Building Information Modeling, Sailing on Uncharted Waters*, Conference Paper, ABA Forum on the Construction Industry, October 2007, p. 30, 31.

[48]*Id.*, O'Brien also agrees that the contractor's participation in design undermines the *Spearin* implied warranty, at least with respect to aspect of the design where the contractor contributed.

[49]It should be noted that this distinction is less important in fully integrated projects because liability is waived or limited between the parties and compensation is determined by project, rather than individual performance. Although not unimportant, in an integrated project the model becomes a means to achieving project goals rather than a yardstick for judging individual responsibility.

[50]The American Institute of Steel Contractors, a pioneer in supporting modeling, has always maintained that the model should be a relied on contract

document. See, e.g., Appendix “A” to the *AISC Manual of Steel Practice*.

[51]Although not publicly available as this paper was being written, in January of 2008he Corps released its hybrid BIM specification “Attachment F” for use by its Project Representatives. As an example of a hybrid provision, the publicly released drafts require use of USACE approved software, open standards and IFC compliance, and modeling of anything normally shown at 1/4 inch scale. In addition to the prescribed standards, the specification states that the model should be sufficient for costing (a performance standard) and require the design-builder to submit a plan that includes for development of the digital model more detailed protocols after contract award.

[52]On March 13, 2008, AGC announced that it was issuing its *Building Information Modeling Addendum* to be used with the ConsensusDocs standard form agreement. Previously, AGC had issued its *Contractor's Guide to Building Information Modeling* to assist contractor's in understanding and implementing BIM.

[53]Teicholz, P. as reported in AEC/Bytes Viewpoint No. 4, April 14, 2004 and elsewhere.

[54]CII (2004).

[55]C. Ibbs, et al., *Determining the Impact of Various Construction Contract Types and Clauses on Project Performance*, CII (1986).

[56]*Optimizing the Construction Process: An Implementation Strategy*, WP-1003, Page 4, The Construction Users Roundtable, July 2006.

[57]*Collaboration, Integrated Information and the Project Lifecycle in Building Design, Construction and Operation*, WP-1202, The Construction Users Roundtable, August 2004.

[58]*Optimizing the Construction Process, supra*, at 14.

[59]*Id.*

[60]**http://www.ipd-ca.net**

[61]In 2007, AIA revised Position Statement 26, Project Delivery, to state:

> “The AIA believes that every project delivery process must address the quality, cost-effectiveness, and sustainability of our built environment. This can best be effected through industry-wide adoption of an integrated approach to project delivery methodologies characterized by early involvement of owners, designers, constructors, fabricators and end user/operators in an environment of effective collaboration and open information sharing. The AIA also believes that an architect is well qualified to serve as a leader on integrated project delivery teams. The AIA further believes that evolving project delivery processes require integration of education and practice in design and construction, both within and across disciplines.”

[62]**http://www.aia.org/ipdg**

[63]*Integrated Project Delivery: A Guide*, explanatory note at page 20, AIA/AIACC 2007.

[64]*Integrated Project Delivery: A Working Definition*, AIACC 2007, p.1.

[65]*Integrated Project Delivery: A Guide*, §4.1, AIA/AIACC 2007.

[66]**http://www.leanconstruction.org**

[67]The collaborative documents are the 300 series ConsensusDocs and are available at **www.consensusdocs.com**.

[68]If the participants have prior collaborative experience, especially if with each other, then the process costs are greatly reduced. The author is aware of integrated projects as small as $10 million, but the teams had prior experience with each other and IPD, and were already committed to the process.

[69]If you evaluate a designer's services from a value perspective, it is apparent that designer undercharge for the truly valuable and creative effort that occurs during the early phases of a project and then "make up" for the shortfall by selling many units of clerical work during the construction documents and sometime construction administration phases. If the latter phases are reduced, design professionals will need to increase their "creative process" compensation.

[70]These conclusions are less applicable to "hybrid" IPD agreements. For example, if liability is not waived, but only limited, the parties still have an incentive to assign blame. This can undermine joint problem solving. Thus, by being more "contractually conservative" the parties may actually increase their potential risk.

Appendix A: Building Information Modeling in a Nutshell

What is Building Information Modeling?

The National Institute of Building Sciences[1] defines Building Information Modeling as follows:

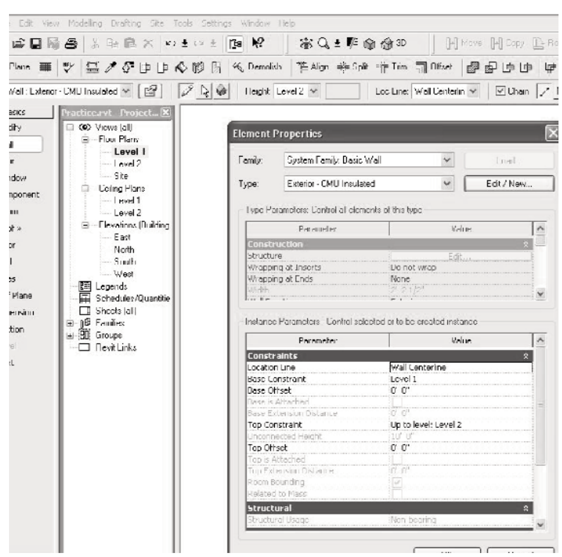
> A Building Information Model, or BIM, utilizes cutting edge digital technology to establish a computable representation of all the physical and functional characteristics of a facility and its related project/life-cycle information, and is intended to be a repository of information for the facility owner/operator to use and maintain throughout the life-cycle of a facility.[2]

Several aspects of this definition deserve discussion. Although the definition references a Building Information Model, yet in current practice the design is built from a set of interrelated models that can exchange information between their differing software platforms. It is this federated set of models that comprise the totality of digital information about the facility and, for the purpose of this definition, are the Building Information Model.

The definition is also interesting for what it does not mention. The definition does not mention three dimensional modeling although this is one of the most visible and immediately understood aspects of BIM. This omission is explained in the phrase ". . .a computable representation of all the physical. . . characteristics of a facility. . . ." The computable representation is a scintillation of all physical characteristic such that three dimensional views become just one logical manifestation of the model. In BIM, three dimensional design is an inherent feature, not an enhancement.

Third, the descriptor ". . .all the physical and functional characteristics. . . .expands BIM beyond earlier three dimensional design tools. In BIM, the building is not just a three dimensional picture. Instead, it is a digital simulation of the facility that can be viewed, tested, designed, constructed and deconstructed digitally. This promotes iterative design optimization and the ability to "rehearse" construction before ever moving labor, material, and equipment into the field.

Figure 1: Element Properties in Autodesk Revit



The information maintained in a BIM also differs from the level and type of information maintained by traditional design tools. In traditional CAD, a wall or other elements is an assemblage of lines that, at most, define the geometric constraints of the wall. In BIM, the wall is an object[3] that contains a broad array of information in addition to physical dimensions. Rather than draw lines that describe dimensions of a design, designers organize intelligent objects into a design. Figure 1 is a screen shot from Revit Architecture 2008 showing element properties of a wall type (Exterior: CMU Insulated in this example) as well as values for the specific instance in the design.

In addition to containing detailed information about the element, the building information model contains information about how the element relates to the design in general and to other objects. This parametric architecture allows the model to adjust to design changes without having to individually adjust every individual element. The CMU wall, in the prior example, "knows" that it is supposed to extend from the foundation up to Level 1. If either of those parameters are changed, the height of the wall will automatically adjust to match. This increases design efficiency and reduces potential for errors.

Because the BIM is a "computable representation," every manifestations of the BIM is automatically current. For example, sections or elevations are just different manifestations of the BIM information. If you make a change in plan view (and, therefore to the underlying BIM data), the elevation and section views that are built from the same BIM data will automatically reflect the changes. Without any further intervention, schedules, tables and other related data reflect the updated information. This also increases design efficiency and makes it virtually impossible for drawings to be internally inconsistent.

In addition, the BIM contains data concerning the object attributes that can be extracted to as schedules, tables, bills of materials or other data that can be printed, evaluated, or sent to other programs for analysis. Again, because the information is based on the central model, and reflects the current design, the potential for error is reduced.

The definition continues by including, as information in the BIM, "…and its related life-cycle information…." This indicates that the BIM contains the functional information necessary to evaluating the operational facility and optimizing its performance for efficiency, sustainability or other criteria.

Finally, the definition states that the BIM is to be a "repository" of data for facility management. The BIM is meant to be a living document that owners can use to manage their facilities as well as build them. BIM's potential for facility management is perhaps its most important role, but it is a role that is just beginning to be explored.

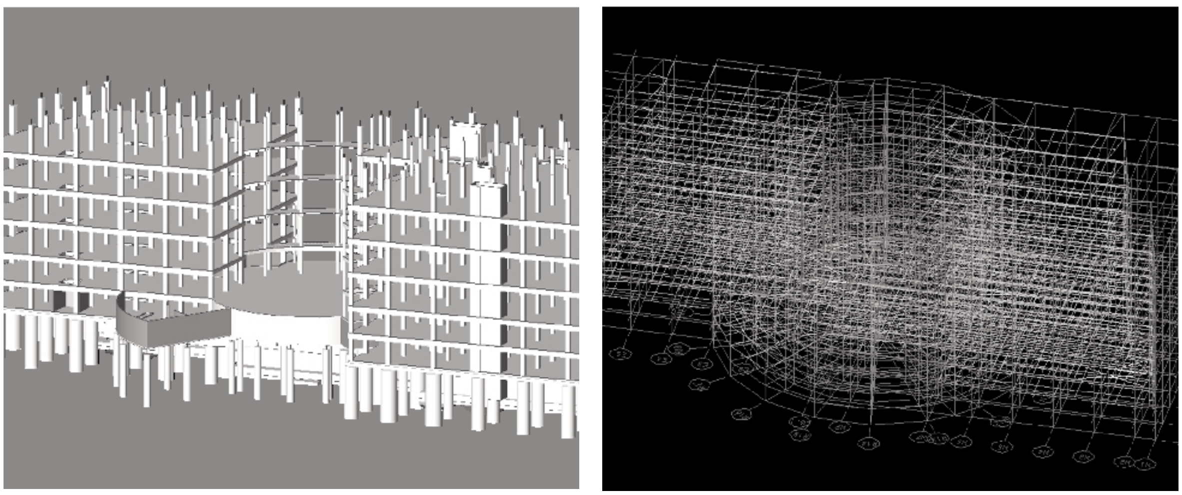
How is BIM Being Used?

Single Data Entry; Multiple Use

Traditional construction practices require the same information to be used multiple times by multiple organizations. Identical information is entered into different programs that provide specific solutions, such as structural analysis, code compliance, material quantities or cost estimates. Every repetition is an opportunity for inconsistency and error. Moreover, even if information is digitally translated from one program to another, translation can alter or corrupt the data. And versioning can be a nightmare, even with compatible programs. Drawing backgrounds are a recurring example of this problem. The architect's consultants need to upload and maintain the basic design backgrounds they receive from the architect. These backgrounds, however, will change as the design develops and each party must take considerable care to ensure that they are working with the latest versions of the basic documents. The contractors and vendors must take the information provided by the designers, often in paper form, and enter it into their systems. As the design develops, changes in one party's documents must be transferred back to the others. Errors begin to creep into the documents because updates are incompletely or incorrectly entered, and work can be wasted because parties are working from outdated information Figure 2, below, shows an example of structural design information in the Revit structural design model and in ETABS, a structural analysis program.

By consolidating information into a unified data source, the likelihood of data entry, translation, or versioning errors is greatly decreased.

Figure 2: Structure Design in Revit and ETABS



Design Efficiency

Although the greatest efficiencies are obtained when BIM is used collaboratively, BIM design can aid a traditional design process. BIM software can reduce the cost of preparing 2D drawings in a conventional project, especially when designs are changing rapidly.[4] For example, in Revit®, any change in plan view automatically updates any section affected by the change. In Tekla Structures, changes in dimension or geometry automatically update details and related features. Moreover, using data rich elements instead of drawn objects, accelerates creation of contract drawings.

Consistent Design Bases

BIM modeling ensures that all parties working from the model share the same base. Under current practice, not all participants may be operating directly from the model. However, if the participants are using software that is compatible with the model, the base information can be moved, imported, or exported from the model. Moreover, periodic imports into 3D visualization software, such as NavisWorks's Jetstream®, quickly exposes inconsistencies.

3D Modeling and Conflict Resolution

The BIM model can render the design in three dimensions and does not require separate software to explore the model visually. This allows better exploration of space, visualization of light studies, and improved communication and understanding of design concepts within the team and with project stakeholders.

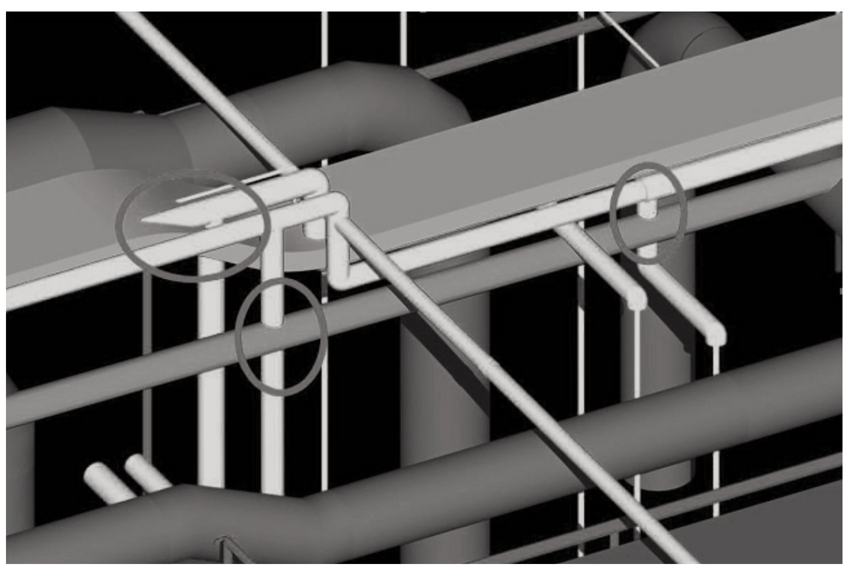
Conflict Identification and Resolution

On complex projects, conflict identification and resolution is an extraordinarily expensive and difficult task. In many instances, designers do not have the time or budget to fully explore and resolve conflict issues. In other instances, full coordination cannot be accomplished during the design phase because the contractor will later design key systems, such as HVAC or life safety equipment that is not reflected in the design drawings. Even in a complete design-bid-build project, construction details and layouts may require information regarding the actual equipment that will be installed.

This information deficit is typically addressed by warning the contractor that the design is “diagrammatic” and that coordination will be required. Traditionally, the contractor coordinates physical drawings of different systems by overlaying them on light tables to determine if the various systems can actually be constructed in the allowed space. Alternatively, drawings for each discipline are merged and printed as color-coded composite drawings. Conflicts that are identified are brought to the designer’s attention through the request for information process, where solutions can be developed and clarifications issued. But light table resolution is inherently a two dimensional process applied to a three dimensional problem. It is notoriously difficult and fraught with error. For these reasons, conflicts are a primary source of contractor claims.

Building Information Modeling greatly reduces conflict issues by integrating all the key systems into the model. Design BIM systems can detect internal conflicts and model viewing systems, such as NavisWorks®, can detect and

Figure 3: Clash Detection in NavisWorks Jetstream



highlight conflicts between the models and other information imported into the viewer. The solution can then be checked to ensure that it resolves the problem and to determine if it creates other, unintended, consequences.[5] In a complex project, the savings derived from coordination can completely offset the model's cost.

Take-offs and Estimating

The model contains information, or can link to information, necessary to generate bills of materials, size and area estimates, productivity, materials cost, and related estimating information. It avoids the processing material take-offs manually thus reducing error and misunderstanding. Moreover, the linked cost information evolves in step with the design changes. The estimating advantages are so significant that some contractors will create models on 2D designed projects to use the model's estimating capabilities.

Shop and Fabrication Drawing

In some instances, the models can provide construction details and fabrication information. This reduces costs by reducing the detailing effort and increases fabrication accuracy. In addition, because conflicts are resolved through the model, there is greater confidence that prefabricated material will fit when delivered. This allows more construction work to be performed offsite in optimal factory conditions. Subcontractors in the steel and MEP trades, regularly use models to fabricate their products.

Visualization of Alternative Solutions and Options

Because it is inherently a 3D process, models are excellent methods for evaluating alternative approaches. Moreover, the ability to evaluate how changes affect key attributes, such as energy use, enhances the model's usefulness as a thinking tool. However, the software interface can interfere with the creative process. In a study of one system, users noted that it was not "sketchy," and therefore impeded the initial creative process.[6] This may lead to using free form design tools initially with the results being loaded into the BIM system for refinement.[7]

Energy Optimization

Building Information Modeling systems, such as Autodesk's® Revit®, can provide information for energy analysis. They can be used to evaluate lighting design and options, are in conjunction with their material take-off capabilities, and can generate documentation necessary for LEED™ certification.[8]

Constructability Reviews and 4D Simulations

Using the model, the contractor can visualize the entire structure, gaining a greater understanding of the challenges involved in its construction. By integrating 4D capabilities, the contractor can also simulate the construction process, which significantly increases the contractor's ability to evaluate and optimize the construction sequence. The interaction between scheduling software and the model can also be used to evaluate the effect of construction delays and errors.

Reduced Fabrication Costs and Errors

The ability to use information in the model to directly create fabrication drawings avoids a problematic and difficult step in the construction process. In a traditional work flow, the fabricators must review the plans and specifications, prepare fabrication drawings, compare them to other fabrication and design drawings, have them reviewed by the design team, and eventually release the drawings for fabrication. Errors can occur at any stage. By using the data in the model, dimensional errors, conflicts, and integration errors can be avoided or significantly reduced. In addition, the model can be updated with as-built information allowing accurate fabrication of custom components, such as building facades.

Facilities Management

If the model is properly maintained during construction, it becomes a tool that can be used by the owner to manage and operate the structure or facility. Modifications and upgrades can be evaluated for cost effectiveness. Data contained in the model can be used for managing remodeling, additions and maintenance.

Functional Simulations

The 3D and conflict checking mechanisms can be used to simulate and evaluate emergency response and evacuation. For example, NavisWorks® was used at the Letterman Digital Arts Center to assure that fire response vehicles could navigate the parking structures.

Summary

Building Information Modeling is the most powerful tool yet conceived for integrating design, construction and management of facilities. It allows designers to explore alternative concepts and iteratively optimize their designs. Contractors can use the model to rehearse construction, prepare cost data, coordinate drawings, and prepare shop and fabrication drawings. Owners can use the data to manage maintenance and facility renovation. And together, the parties can use Building Information Modeling as a basis for collaboration.

ENDNOTES

[1]National Institute of Building Science is responsible for the National Building Information Modeling Standard (NBIMS).

[2]**www.nibs.org/newsstory1.html**

[3]Terminology varies between software platforms. However, there are at least three types of objects in any program. Class objects that have properties appropriate to everything in that family. Walls, for example, are a family. Subclasses are specific types in a family, for example, an 8 foot masonry wall. Subclasses inherit the attributes of their family and add attributes appropriate to the subclass. Classes and subclasses are essentially descriptions, not the object itself. Instances are the individual examples of a subclass in the design. This hierarchy makes it possible for designers to quickly create new component types by subclassing an existing component type, adding or modifying attributes, and then creating as many instances of the newly design component as desired.

[4]In discussion with the author, design firms with significant BIM experience have reported 50% reduction in time to produce drawings as compared to conventional 2D CAD drawing.

[5]NavisWorks® was used to model LucasFilm's Digital Arts Center and identified several significant conflicts before construction commenced and was used to check field construction, again identifying mislocated elements and penetrations.

[6]L. Khemlani, *Autodesk Revit: Implementation in Practice,* Arcwiz, 2004.

[7]Supporting graphic creativity is already being addressed by the primary software houses. For example, Autodesk's Architectural Desktop® and Google's Sketch Up®.

[8]*Building Information Modeling for Sustainable Design*, Autodesk® 2005.