BIM: Building Information Modeling

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BIM

Look inside a construction trailer. There's a plan rack with separate drawings for architectural, mechanical, plumbing, electrical and civil. There are special sets of drawings for landscaping, lighting, security networks, wayfinding graphics and so on. Shop drawings are in racks, buckets or drawers. Book shelves hold loose-leaf notebooks full of RFIs. Other drawings reflect a change in requirements or corrections to the initial drawings.

Each of these documents describes a piece of the project. None describes it all. Few people have access to a central collection of documents. Information entered in one place may not be replicated (or accurately replicated) in the other places it is needed.

The multiplicity of documents is produced by the multiplicity of contracts. It reflects the many organizations—architects, engineers, consultants, subcontractors and manufacturers—that contribute to the work. And it reflects the sorry fact that our industry has great difficulty integrating these work products.

Building Information Modeling promises to bring huge improvements to the construction industry. There is no technical reason that the sets of design drawings and shop drawings couldn't be integrated into a single electronic model—updated with RFIs and change orders as the project progresses.

There is not an integrated set of drawings to build from. The architectural and engineering drawings are separate.

And shop drawings abound.

What if the movie industry treated its customers that way? Assume that you went to Blockbuster to rent a movie and got separate DVDs for the parts of the heroine, the hero, the villain, the bit players, the sound track, the scenery, the special effects—and so on. Then you go home and you discover the program is out of sync: the hero swings a punch at the villain and the villain isn't there. Something hasn't been coordinated. So you send Blockbuster an RFI. Blockbuster's policy is to turn it around in three weeks. Then the movie producer changes the plot and distributes updated DVDs.

BIM is a documentation tool, replacing legacy drafting procedures. But BIM it also a technology for collaboration, an integration tool for our fragmented and specialized building industry and a vehicle for an IPD Team to pool its intellectual capital. As we approach a robust implementation of BIM, it will let us build virtually, before building physically, uncovering problems of sequence, interference and constructibility that trigger change orders and RFIs.

Evolution of BIM

Vector CAD: The first generations of CAD represented buildings with geometry—vector based lines, arcs and circles. A CAD drawing was easy to modify and replicate. It also provided greater precision than pencil on paper. But it was dumb: lines drawn with a computer instead of a pencil.

Object CAD: Then "smart" objects with properties were added. Objects like windows, doors, walls, roofs or stairs had properties that governed their behavior. A window could be pulled from a resource file into a drawing and stretched to fit the required opening. As it was stretched, the panes would grow but the jamb section would not. A user could associate information to the object such as the supplier, part numbers, the finish, the warranty and so on. The drawing objects were "smart." They knew how to behave and what they were.

BIM: From that point, it was a logical step to envision an entire building as a smart object with endless possibilities for algorithms that govern its behavior and associated information. BIM emerged. It's an awesome vision.

BIM Characteristics

A BIM model is a digital description of a project. It may include information such as the physical configuration, programmatic requirements, functional characteristics, specifications, systems performance, supply chain threads, construction sequence, cost or any other information that might be useful.

Plug-ins: Specialized software may be "plugged in" with algorithms that can adjust related building systems if there is a design change. These "plug ins" can include programs for structural and mechanical design. For instance, if a room is enlarged, the size of the structural members can be automatically recalculated and resized. The model adjusts itself. If the building is rotated on the site, the heat gain and loss may be recalculated. Other plug-ins may focus on energy analysis, LEED certification, cost estimating or construction scheduling.

Reports: BIM ideologues will quickly tell you that BIM is not drafting software. It is a database. Drawings are simply one form of report. Like any digital database, a BIM model can produce reports—subsets of information for special purposes. These reports can be in the form of 2D or 3D drawings or an infinite variety of custom alphanumeric reports. The IPD team can tailor reports for specific purposes instead of grappling with a large set of 30" x 40" construction drawings and a fat set of specifications that obscures required information.

For instance, architects can produce a report in 3D and in color, rendered for comprehension by non-technical people. They can deliver drawings for review by entitlement agencies (building permits, accessibility requirements, environmental concerns, aesthetic compatibility or whatever) that address the agency's specific requirements. Assembly details can be produced on site for current construction challenges. Facility managers may access life-cycle, maintenance and replacement information.

4D and 5D models: BIM can have sequence and construction duration information attached to drawing elements that represent the building systems (4D modeling). A computer program can animate construction progression. A user can input a date to observe current state of completion. The builder can analyze on-site material staging problems, develop phasing plans, improve the sequencing of trade contractors or analyze the cost of construction delays. Cost can also be attached to drawing elements that represent building systems (5D modeling) for estimating and value engineering. The estimate can progress in lockstep with design.

Clash Detection: At the simplest level, pasting shop drawings into a CAD drawing quickly indicates a misalignment or a poor fit. Even in a 2D model, it is obvious if a window doesn't fit between a pair of columns. However, problems are not always that obvious in 2D models. Conflicts are often caused when a building system designed by one consultant interferes with a system designed by another consultant on separate drawings. For instance, if a lighting consultant locates recessed light fixtures on an architectural reflected ceiling plan without checking beam locations on structural drawings, the recessed can may poke into a beam. And we have all experienced a mechanical engineer plotting duct runs that pass through the structural engineers' beams. BIM software provides sophisticated "clash detection" routines that indicate when two systems or products occupy the same space.

Direct fabrication control: Traditionally, fabricators develop shop drawings based on their interpretation of the plans and specifications. They are checked by the AE. Errors occur at each translation. By pasting shop drawings directly into the BIM model, errors and conflicts are more apt to be detected. Ultimately, a BIM model may include algorithms for CNC[1] direct fabrication of building systems, such as ductwork, curtain wall, millwork. While there are still opportunities for error in these automated processes, they are reduced and often eliminated. Precision is increased and supply chain workflow is shortened.

Facilities Management: An integrated BIM model is a good bit more valuable to facility managers than typical "as built" drawings. It may contain warranty data, spare parts lists and sources, useful life expectations and maintenance recommendations. It may contain original layouts as well as remodeling and renovation documentation.

BIM as a contract tool: Although IPD may minimize the contractual silos between the members, it is unlikely that an IPD team will include 50 to 75 subcontractors. Contractual separation will remain for most of the design and construction team. Multiple customized reports from a BIM model will assume important roles as contractual tools. The tools will work both ways—clarifying agreements with both the owner and with subcontractors.

The initial agreement with the owner will likely be a written document, perhaps with some simple diagrams to describe the intended result. As the project progresses, printed reports from the BIM can then augment that original agreement, defining the work for staged approvals just as traditional SD, DD or CD documents have done. However, rendered 3D reports from the model will do a better job of ensuring a meeting of the minds with the owner or users who may lack experience with technical Construction Documents.

[1] Computer Numerical Control refers to computer instructions that drive machine tools used to fabricate components. The technology is labor efficient, accurate, repeatable and facilitates complex forms.

The BIM will then become the framework for describing the work to subcontractors. As the design develops, subs will be asked to propose or bid on aspects of the work. When selected, aspects of their technical proposal may become part of the BIM—to be augmented or replaced with shop drawings as their work is developed.

Managing a BIM Model

Managing the assembly of a BIM model is analogous to managing the assembly of a building. Consider this analogy. A construction manager must understand the technology of construction. But the more crucial job is orchestrating the work of hundreds of organizations—coordinating the assembly of materials on-site with decision-making, sequencing, and supply chain management. Most of a project is built off-site. If the on-site management team doesn't manage the off-site activities there will be delays. Managing the interrelationships is as important as understanding the technology of the work. In the simplest sense, it doesn't do any good for a construction superintendent to know about forming and finishing concrete if the concrete truck isn't scheduled for delivery at the right time.

A BIM model has similar requirements. Managing the development of a virtual construction model requires skills that are similar to managing the real thing. Too often BIM production is staffed with people who understand BIM technology but don't understand how to manage the workflow from multiple sources.

The management job requires setting BIM standards, understanding constructibility and construction sequence, evaluating supply chain data and vetting information that is submitted to be input into the model. But most of all, it requires understanding how to suck this information from multiple sources into an integrated model. The manager must have clout in the organization to get the attention of the extended IPD team to schedule information flow, analysis and problem solving. And since inputs to a BIM model may ricochet through the model, the manager must review and evaluate the accuracy of inputs—just as a CFO ensures that there are procedures to evaluate the inputs of financial information before they are posted to a general ledger.

A BIM model manager requires the support of the IPD management committee who must set policies to adopt the technology, buy and install the software for members who do not have it, train the team, champion the use. Finally, they will need to establish workflows for a BIM process that may be developed by the BIM model manager.

An IPD team needs a BIM manager and an interdisciplinary BIM team staffed with people from member firms. The BIM team integrates drawings from the AEs, subs and manufacturers. They develop 4D and 5D models. They detect coordination problems with clash detection routines. Constructibility reviews trigger design adjustments—made with the collaboration of the AEs. RFIs are anticipated and if collaboration ongoing, should be minimal. In developing the model, questions surface before construction.

The BIM model manager must be a person with good interpersonal skills to build the collaborative culture required to produce an integrated BIM model. The manager must build trust and networks of personal communication within the contracting team. As with real construction, the more personal contact and the more trust, the more collaboration. BIM allows trust to be built early, well before construction begins. There's an opportunity to allocate model space to each subcontractor to give them confidence that the process will not only find clashes in their systems before they get to the field, but that the sub will have the ability to model the clearances and working space needed to install their work.

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Architects have typically been the primary source of BIM models, fulfilling their traditional role in developing the drawings and specifications that document the *product*—the description of the design, the intended physical result.

CMs have usually taken the lead in providing project management information (PMIS) systems—gathering and integrating data from the extended project team. These systems have concentrated on *process*—tracking contractual matters such as cost, schedule and quality control; RFIs and change orders.

But now CMs are developing in-house BIM teams and are developing BIM models prior to construction.[2] BIM is not the exclusive territory of the AE—nor should it be.

Eventually, it is likely that an IPD Core Team will build integrated groups to produce integrated documents. Clearly, managing virtual construction will require technical knowledge of both *process* and *product*. Virtual construction will require AEs with product expertise and CMs with process expertise. It will require effective collaboration. IPD will provide the platform.

Ultimately, the IPD Core Team will likely build integrated groups to produce integrated documents.

[2] AGC has published *A Contractor's Guide to Building Information Modeling, Edition One*, that guides contractors in the use of BIM.

Dynamic, Living and Incomplete Model

An idyllic vision of BIM is that of a fully integrated and complete BIM model—a virtual representation of the building, available for study before construction begins. It would include construction details, specifications, cost, schedule, warranties, products, systems, construction sequences, off-site fabrication schedules and shop drawings. It would contain 4D schedule data and 5D cost data and be enabled with CAD-CAM instructions for driving machine tools in off-site shops. Wow!

Then, to continue the idyllic vision, the extended IPD Team (AEs, CMs, subs, manufacturers and fabricators) could pour over the model and find construction problems in electronic space before entering the costly physical space of the real world. They would get the change orders and RFIs out of the way before construction begins and they would validate the workflow and supply chains.

It's not entirely a foolish pipe dream. Many owners have continuous building programs. They may have prototype designs or at least projects with many similarities. They may have BIM models of building models that can be assembled in various ways for variations in their project needs. They may have in-house staff or continuous relationships with AEs, CMs, subcontractors and suppliers. They can develop continuous improvement for feedback after each project into a prototype BIM model to further refine its value. It's conceivable that these owners could approach that vision.

However, consider the realities of a more typical project. AEs avoid including final details in the Contract Documents so they can maintain competition among multiple manufacturers. Subcontractors, manufacturers and fabricators don't detail their systems until they are under contract. Final construction details aren't available until after products and systems are purchased. And if a project uses fast-track scheduling, complete coordination can't be done in electronic space before construction begins because the design is incomplete.

Furthermore, many subcontractors and suppliers are not BIM literate and those who are may use incompatible software. So the BIM model will be incomplete, augmenting the electronic database with legacy CAD or paper products.

Always limited: For the foreseeable future, a BIM model will be less than ideal. It must be a living, dynamic thing, accepting additions and changes throughout the project's life—continuing to grow after occupancy.

All the vision of a complete model for virtual construction is possible, and all the capabilities mentioned above are within our technological reach, only some are implemented on any project. A BIM model manager must then decide, given the sophistication of the project team, how far to go.

Barriers to BIM

The ultimate objective is to build an integrated BIM—a virtual building before we make expensive mistakes with concrete, glass and steel. But tradition, contractual separation, archaic laws, technical limitations, interoperability problems and culture hinder us.

Software and hardware constraints: A BIM model theoretically has unlimited ability to hold information. But any practical project model will fall short of what is theoretically possible. Despite faster and faster computers and more efficient software, the model slows down as it enlarges.

Cost practicalities: At some point, it becomes impractical to add detail to the model. We still assume the builder will use some judgment in the field. A drawing doesn't need to show all the nail locations in a wood frame.

Universal adaption: The fruition of BIM will depend on widespread use by designers, contractors and manufacturers. But until trade contractors and manufacturers are operational with BIM, we will limp along with incomplete integration.

Interoperability: Any CM or PM that has managed a program that included multiple architects and multiple CMs has faced the frustrating problems of interoperability in trying to integrate data from different project management information systems. It is hard to share data between Autodesk's Constructware, e-Builder and Meridian's Prolog. The same problem exists with BIM software.

A fully integrated BIM model is a vision, not a reality. At current levels of development, architects engineers, consultants, builders and fabricators may have independent BIM models, legacy CAD systems and legacy paper systems. Those who use BIM software may not use the same programs.[3]

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[3] The International Alliance for Interoperability (IAI) (www.iai-international.org) functions as a council of the National Institute of Building Sciences (www.iai-na.org) to improve interoperability. The National Institute of Building Science (NIBS) is defining BIM standards. The Facility Information Council (FIC), a NIBS Council, (http://www.facilityinformationcouncil.org/) "provides support for the development, standardization, and integration of computer technologies and software to ensure the improved performance of the entire life cycle of facilities

Document signing: The largest part of an architect or engineer's fee is compensation for producing Construction Documents. Then 40-60% of the Construction Drawings are discarded and replaced with shop drawings—about 1-3% of the project cost is wasted.

Integrating shop drawings in a BIM model eliminates this time-consuming and costly redundancy. It also solves problems. If fabricated products don't fit in the 3D space properly, the problem is likely to surface and get fixed.

However, most state laws stipulate that architects and engineers must only sign drawings done under their supervision. So AEs are properly reluctant to sign documents that include drawings prepared by others.

The typical solution for this annoying problem is for an IPD Team to simply produce a sub-set of the BIM model that has been produced under the AEs supervision for the designers to sign. Then the IPD Team calls the integrated BIM model a constructibility set, shop drawings for the building, a quality control document or whatever.

Although BIM software is useful in documenting the work of a single company, its greater value is that of integrating the work of multiple companies—sharing designs, specifications and information among the extended project team. But sharing blurs authorship and blurred authorship blurs responsibility for the design.

The process of assembling companies necessary to design and build a structure has assumed separate contracts, responsibilities, scopes, liabilities—and separate but clearly allocated and defined risk and responsibility. Statutes, case law and insurance products reflect these contractual silos.

The traditional assumption is that the AEs are responsible for the drawings and specifications. If shop drawings are integrated in BIM the AEs are concerned that they will assume responsibility for their accuracy and the performance of the product. So in project delivery processes with separate contracts, the AE is circumspect about integrating shop drawings. Practitioners and their attorneys partition responsibility by partitioning drawings—balking the development of integrated drawings and crippling the benefit of BIM.

One approach has been to add shop drawing to the BIM model clearly identified in the model as the sub's work. The sub would

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from design, engineering and construction through operation, maintenance and retirement phases."

retain responsibility. However, if the AE and the sub collaborate (a desirable activity) the responsibility becomes unclear.

Until the licensing laws and the insurance industry catch up with technology and practice, it will be necessary for the AE team to print a report from the BIM model that depicts design work that they can comfortably claim has been produced under their supervision. Then they can sign the drawings and obtain required permits. Then the IPD Team can move ahead and integrate drawings as extensively as possible. The BIM can be characterized as a "Quality Control" or a "Virtual Construction" document.

Who Pays for BIM and Who Benefits?

A BIM model improves the design, improves coordination, reveals construction problems and helps the IPD team optimize both product and process. Savings in time, money and grief pay for its cost.

However, in traditional processes the cost of a BIM model is borne by the AE, but the savings benefit multiple sources—the AEs, the CMs, subs, suppliers, manufacturers and, of course, the owner. The cost of building an integrated model surpasses the usual cost of producing typical Construction Documents and so, in projects where AEs are paid a traditional fee, the AE objects to the idea of assuming the total responsibility of managing and developing an integrated model. However, in an IPD project, the management committee can agree to fund and staff the required effort and the extended IPD Core Team can contribute resources. Since the benefit is to the project, it can be paid for by the project—not by a single project participant.

Legal Conundrums

Intellectual property: Traditionally, AEs have attempted to retain ownership of the construction documents, although owners, particularly serial builders, have challenged that with increasing frequency.

In a traditional process with separate contracts, the ownership becomes murky. But with IPD, it is likely that the members of the IPD Core Team will argue that since the BIM model is a collaborative work, it belongs to the members. It can be argued that each of the collaborators has an interest represented by their contribution. They can share it among themselves in parts or in whole—however they agree.

But since the BIM will morph into a useful tool for the facility managers, owners will also want ownership—and in those legal relationships where the owner is a member of the IPD Core Team, they will likely have ownership.

However, it is likely that the IPD Core Team will want a contractual restriction on the owner's ability to use the model for future construction—or permission with indemnity of the IPD Core Team.

Digital information in a BIM Model can be easily copied and reused. Subs, their manufacturers and suppliers may provide proprietary designs to the BIM and may require agreements that prevent fabrication or reuse of the design by others. Confidential processes may be used that must be protected. Access and use of the model must be defined—either in the contracts that form the legal relationship of the IPD Core Team or as BIM management procedures.

The AGC BIM Addendum

The AGC has issued a BIM Addendum to their ConsensusDOCS 301. It is a thorough document, clearly written by construction professionals and lawyers who understand BIM and have thoughtful approaches. It's educational and informative. The concepts should be understood by any construction professional involved in a BIM initiative.

The Addendum is designed for traditional processes such as design-bid-build or negotiated GMPs and avoids rupturing traditional legal relationships among the owner, architects, engineers, GCs, subcontractors, suppliers and manufacturers. It is designed to be attached to any project contract including subconsultant and subcontractor contracts.

It defines a model as a "Contribution" from one of the project participants.

- There are multiple models for analysis, preliminary design studies or renderings.
- A *Full Design Model* includes architectural, structural, MEP and other design phase models and is analogous to traditional Construction Documents.
- A *Construction Model* includes shop-drawings and related information. It might include information imported from a Design Model or from traditional Construction Documents.
- A *Federated Model* is an assembly of models. The models must maintain their authorship and remain separate. The models can't be interactive: one model must not be affected by a change in another model. They

can be linked so they can be used for approvals, coordination, quality control, clash detection, estimating or, ultimately, facility management. However, no one can change another's model so clear responsibility may be maintained.

To maintain authorship identify and responsibility the Addendum assigns tasks and responsibilities to *The Information Manager* who must control access to the model and record each input, deletion or change with the author's contact information, date, time, etc., and maintain an audit trail of such modifications.

The BIM Addendum also:

- States that if there is a software malfunction, the owner bears most of the risk and that a party to the BIM Addendum may be entitled to a time extension or other requirements.
- Requires that each party agree to waive claims against the other parties to the agreement for consequential damages.
- Requires model users to minimize claims and liability caused the models, by quickly reporting errors or omissions that it discovers.
- Provides rights to the owner to use the model depending on the agreement between the owner and the design professionals.

Each party to the BIM Addendum warrants to the other parties that it has rights to the copyright of its Contributions and agrees to indemnify and hold other parties harmless for claims of third parties claiming a copyright infringement. And each grants the other parties a limited, non-exclusive license to use that party's Contributions.

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The melancholy aspect of the AGC Addendum is that, despite the wisdom of the authors, it is predicated on using powerful integration software for a non-integrated process. Keeping design and construction models separate is inefficient and neglects useful collaboration, construction feedback to designers, quality control and value engineering initiatives. The need to maintain model separation precludes interactive relationships and thereby gives up much of the potential power of BIM. The contractual separation of the key team members creates much legal boilerplate and procedural documentation. It is not a Lean process. But that's not the fault of the AGC or the authors of the Addendum. It's our industries burden of tradition.

The BIM Addendum falls short of envisioning an integrated, seamless design and construction process that allows us to build virtually before we pour concrete. But it wasn't intended to do so. And we all recognize that vision is at the top of a long hill to climb. It will be wonderful when we can watch the technical understanding and intellectual energy that went into the AGC BIM Addendum applied to that vision—unfettered by our industry's creaky traditional processes.

What's the Design? Who's the Designer?

The very concept of Integrated Practice distributes the creation of a design across a number of organizations.

- Most owners are serial builders. They create standards and prototypes that they give to AEs and CMs to implement.
- CMs participate in the development of design concepts and affect the design with their recommendations for materials and systems. Constructibility and value engineering studies often have substantial affect on the design.
- Manufacturers and specialty subcontractors produce shop drawings that are intended to implement the design intent.
- Manufacturers and software vendors provide 3D or BIM "content" that describes their products over the Internet for insertion into construction documents.
- Design Assist strategies involve trade contractors in the design process.

The design: A singular advantage of digital files is that they are easy to modify and update. So BIM models tend to be living documents—growing through the evolution of the project as the design develops, as clash detection uncovers problems, as field conditions develop, as changes are made and final configurations are adjusted during construction.

And yet designers need to know what they have designed and are responsible for, owners need to know what they approve, contractors need to know what they agree to build, approval agencies need to know what they have approved and inspectors need to know what to accept. The moving train of a BIM model is a problem when there is a static document required for an agreement with a contractor, and approval from an owner or permission from an entitlement agency. Consequently a BIM model must produce reports that define and freeze these categories of documentation.

In 1857, Otis installed an elevator in a building, something that the manufacturer knew more about than the architect.

The designer: Ironically, in 1857, the year the AIA was founded, Elisha Otis installed a "safety elevator" in a New York building. A manufacturer put something in a building that the manufacturer knew more about than the architect. Since then, industrialization and a competitive environment have driven manufacturers to develop more and more sophisticated building products. The result is that architects and engineers include more and more in their design that they did not design and do not fully understand. They rely on the representation of someone else that a product, a material or a system will perform properly.

In 1857, it was an exception to have industrialized products (like the elevator) in a building. When the professions of architecture and engineering emerged, AEs designed building systems: heating, enclosure, partitioning, roofing and millwork systems. Today, most of a building is manufactured off-site from designs produced by manufacturers. Increasingly, AEs design buildings that include technology that the AEs do not understand as thoroughly as the manufacturer. The AE's job has changed. It is to evaluate and integrate systems and products designed by others.

Recently, the AIA distributed an on-line survey to measure the desire for BIM content provided by manufacturers. They asked for interest in partitions, doors, windows, floor coverings, ceiling systems, kitchen equipment, elevators, furniture, electronics, casework, furniture systems and equipment of all kinds for single family residential, healthcare, commercial/retail, multi-unit residential and hospitality, Lab/Hi-tech/Research, K-12 and "other" kinds of projects. This plentiful and commonly used BIM content, available from the manufacturers, contains algorithms and other properties, developed by the manufacturer's designers that may adjust the object as it is installed to a design.

Software companies are working on BIM software that will adjust related building systems to design changes. For instance, if window areas are increased (increasing heat loss and gain) the ducts will automatically be resized. If floor plans change the software will check code compliance. If a room is enlarged, the beams will get bigger.

"Smart systems" and "smart objects" may not be created by licensed architects and engineers. However, AEs will use increasingly sophisticated software tools and embedded objects downloaded from manufacturers. The design may be distributed to different computer systems and used by different participants.

Conceivably, there can be a dispute over the cause of a malfunction in an elevator system. (For instance, did the rails move because the structure deflected or were they improperly aligned during installation?)

However, as industrialization and information technology continue to make more sophisticated systems available to architects and engineers, and present them to the industry over the Internet as smart self-adjusting objects, the problem of tracking responsibility for design components will become more difficult.

Most software contains licensing agreements that protect the software author from liability in its use. While AEs and CMs may place responsibility on manufacturers for the performance of their physical products, they will be unlikely to deflect responsibility for errors produced with the software they use—any more than a taxpayer could blame TurboTax for underpaying income tax.

The responsibility for the elevator problem is far easier to track than a system problem that was designed with smart content downloaded from a manufacturer, adjusted by a CAD operator, modified by owner standards, value engineered by a CM and interpreted in shop drawings by a subcontractor.

Architects and engineers have traditionally been responsible for the design. At a high level of conceptualization, that will remain true with Integrated Practice. But more often, owners who are serial builders will influence not only design requirements, but design solutions. As the intellectual capital of CMs, trade contractors, manufacturers, suppliers and consultants is added, is it possible for the AE to assume full responsibility for the design?

Or do we need an integrated team to participate in that responsibility?