Building Information Modeling Two Years Later – Huge Potential, Some Success and Several Limitations

Written by: Ian Howell and Bob Batcheler

Introduction

Since the great Building Information Modeling (BIM) debate facilitated by Jerry Laiserin in April 2003, and reported on here in the Laiserin Letter, much has transpired with regard to building information modeling. Pilot projects have been completed, BIM systems have evolved through several versions of software upgrades, and industry leading firms are adopting BIM on live projects. Given the number of companies we have met during our research that have indicated some intention to seriously consider adopting BIM, we felt that it would be useful to document our findings to provide a basis for evaluating BIM and to examine what has been learned. First, for the uninitiated, a brief recap.

CAD versus BIM – A Quick Refresher of the Basics

[Regular readers of the Laiserin Letter should feel fee to skip this section and get straight to the exciting stuff below]

The original premise of a CAD system was to automate the task of drafting. As such, the original focus of CAD applications was to represent 2D geometry via graphical elements, such as lines, arcs, symbols, et al. In this context, walls, for example, are merely represented as parallel lines. To establish some meaning behind these graphical elements, the concept of layering was introduced to group related elements, such as the lines used to represent walls on a given 'wall layer.' By doing so, discrete 2D drawing files could be generated and plotted from CAD, but more complex information, such as the relationships between elements could not be represented. The emergence of 3D CAD initially focused almost entirely on creating geometry in support of visualization, and subsequent advances concentrated on creating realistic rendering and lighting effects.

More recently, object-oriented CAD systems (OOCAD) replaced 2D symbols with building elements (objects), capable of representing the behavior of common building elements. These building elements can be displayed in multiple views, as well as having non-graphic attributes assigned to them. The inclusion of parametric 3D geometry, with variable dimensions and assigned rules, adds "intelligence" to these objects, permitting the representation of complex geometric and functional relationships between building elements. In this paradigm, walls are objects which can be stretched, joined, have height, be of a specific cross-section type, and "own" associated properties, such as a fire rating or insulation value. Similarly, doors and windows are represented as objects, capable of representing their relationship to the walls in which they are placed and behaving accordingly. More importantly, abstract objects, such as a space, can be defined by the relationships between physical building elements, identified (e.g. room number, room name, etc.), described (e.g. area, volume, use, occupancy, etc.), and referenced (e.g. listed in a room schedule, counted to calculate total floor area, etc.). Capturing these relationships and behaviors and the richness of the intelligence are just not possible in the previous CAD paradigm.

Building information modeling (BIM) is the latest generation of OOCAD systems in which all of the intelligent building objects that combine to make up a building design can coexist in a single 'project database' or 'virtual building' that captures everything known about the building. A building information model (in theory) provides a single, logical, consistent source for all information associated with the building.

Which BIM? – Comparing Different BIM Systems

The 'utopia' of BIM was conceived as a single building information model for the entire construction industry. The International Alliance for Interoperability (IAI) pioneered an international technical effort across 19 countries to define a single building model as one authoritative semantic definition of building elements, their properties and inter-relationships. This work has largely been successful with its IFC (Industry Foundation Class) Model now endorsed as a draft ISO (International Standards Organization) standard. However, in the absence of a single model from day one, software vendors aspiring to gain commercial advantage forged ahead with different competing BIM implementations.

In an attempt to help users, the following is a brief comparison (presented in alphabetical order) of the different approaches taken by each of the leading providers of BIM solutions:

Autodesk Architectural Desktop (ADT) provides a transitional approach to BIM, as an intermediate step from CAD. ADT creates its building model as a loosely-coupled collection of drawings, each representing a portion of the complete BIM. These drawings are aggregated through various mechanisms to generate additional views of the building, reports, and schedules as though there was a single BIM at the center. One overhead of this approach is complexity in managing this loosely-coupled collection of drawings and the opportunity for errors if the user manipulates the individual files outside the drawing management capabilities provided in ADT.

Autodesk REVIT is perhaps the most literal interpretation of a single BIM as a central project database. The strength of this approach is the ability to coordinate every building element in one database, thus providing users the ability to immediately see the results of any design revisions made in the model, have them reflected in the associated views (drawings), as well as to detect any coordination issues. REVIT is a proprietary data model which does not currently support IFC import/export, although future IFC support has been promised. For software developers, ODBC links provide limited access to the building model information and a limited application programming interface has been provided in the most recent release.

Bentley Systems interprets BIM differently as an integrated project model which comprises a family of application modules that include Bentley Architecture (which is still also sold in some international markets under its original Microstation Triforma name), Bentley Structures, Bentley HVAC, etc. Bentley describes this approach as an evolutionary path that allows its Microstation users to migrate work practices that still have their origins based on using CAD. Access to project data is provided with DWG and IFC file formats both being supported. However, the highest levels of interoperability are only achieved when the entire family of Bentley products are deployed on a project.

Graphisoft's approach to BIM is to create a virtual building model, meaning their ArchiCAD application is viewed as one of many satellite applications orbiting a virtual building model rather than being seen as the central repository for the entire model. In addition to ArchiCAD being conceived as a BIM system from its inception over 20 years ago, Graphisoft is now working with a consortia of application partners to deploy EPM Technology's IFC-based model server as a virtual building repository, possibly the most innovative technical approach to the future of BIM.

Nemetschek provides a fourth alternative with its BIM platform approach. The AllPlan database is "wrapped" by the Nemetschek Object Interface (NOI) layer to allow third-party design and analysis applications to interface with the building objects in the model. This NOI layer is a published API which also supports IFC objects. Primarily available in the German speaking countries of Europe, this solution provides an evolutionary approach from the traditional approach of Allplan.

BIM – The Promise Versus the Reality

BIM promises and does actually deliver many advantages as a single source of building information:

- Plans, elevations and section drawings, generated as "views" from a single design model, are always consistent
- Coordination of building objects created across different disciplines in a single model resolves clashes between design elements
- Comprehensive (door, window, room, equipment) schedules associated with the building are easily generated and kept up-to-date with any changes to the model
- The availability of a single BIM makes it possible to capture additional information throughout design, procurement and construction of a building, serving as a living record of the building for operations and maintenance throughout its lifecycle

However, experience to date is demonstrating a number of determining factors which complicate achieving the full promise of BIM, including:

- Situational project teams comprised of many participants, each of whom has optimized their work processes to use pre-existing technology already deployed in-house

- Reliance on best-in-class applications from different vendors based on specific project requirements
- Long-standing delineation of professional responsibility and liability among project participants
- An iterative design process caught up in fast-track project schedules, and
- Varying project delivery methods and contractual relationships

The key question is— with all of these factors at play on every real-world project, ***can BIM really work in practice?***

Reality Check #1 – BIM is Being Used on Significant Live Projects

A key difference today, as distinct from the time of the original great BIM debate, is that BIM is now being used on some very significant projects around the globe. In fact, each of the primary BIM vendors identified above has signature projects underway that serve as outstanding examples of BIM's capabilities, while at the same time demonstrating some of BIM's inherent limitations. For example:

Autodesk REVIT is being used extensively on the Freedom Tower in New York City. When completed, the Freedom Tower will be 1,776 feet tall, the world's tallest building, and contain approximately 2.6 million square feet. Based upon an initial start in modeling and design of the concrete substructure, SOM was encouraged through that experience to extend their use of REVIT to the design of the lower level of the building superstructure, and then to model the complex geometry of the distinctive tower. Given the high visibility and aggressive schedule associated with such a large, complex project, SOM's commitment to a full BIM approach to the project is both a bold bet, and the only realistic way to deliver on the unique demands of this project. (More details about this high profile project can be found on the Autodesk website).

The Bart's and The London Hospital project is being designed by HOK's London office with Autodesk Architectural Desktop, using a BIM approach. HOK have been selected as the architect by Skanska Innisfree, the consortium appointed preferred bidder for the largest hospital redevelopment carried out so far in the UK under the Government's Private Finance Initiative. The development proposals are extensive and will provide over 2 million sq ft of new accommodation and a total of 1248 beds. Both hospitals are located in tight urban sites and have challenging geometry and a host of design and planning constraints, including the staging of construction to permit the existing medical facility to remain in operation throughout construction, testing the power and flexibility of a BIM approach to design. (For more details describing the Bart's project visit bartsandthelondon.org.uk).

Bentley Architecture and Bentley Structures are being used to capture existing conditions and facilitate the refurbishment and acoustical retrofit of the world renowned Sydney Opera House. The ability to accurately model the extraordinary geometry of the Sydney Opera House and to capture existing conditions throughout the extensive complex are proving their value as this classic of modern architecture is enhanced to support its mission. The original architect, Jorn Utzon, working in conjunction with Johnson Pilton and Walker, and OveArup, are using Bentley's BIM tools to develop their design throughout several phases of the refurbishment project. (More details about this innovative use of BIM can be obtained from Bentley's website).

The design of the Eureka Tower in Melbourne, Australia was accomplished using Graphisoft's ArchiCAD. At 92 stories and nearly 1,000 feet in overall height, the Eureka Tower is the tallest residential structure in the world. Designed by Fender Katsalidis Architects, the Eureka Tower project is a great example of an architectural firm that has fully embraced the process change associated with a full BIM approach. (Full details are available on the Graphisoft website).

Reality Check #2 – Lessons Learned from the Early Adopters of BIM

Without intending to comment on any one specific BIM system, it does serve us well to "dig deeper" into the lessons being learned by the early adopters who are using BIM for the design and documentation of live projects.

Some limitations that are being discovered and wrestled with include:

- The size and complexity of the files that BIM systems create – For complex projects, the scalability and manageability of a fully loaded central BIM project database represents a major challenge
- Sharing BIM information as drawing files – Users are defaulting back to exchanging documents (drawing files created as views of a building model) rather than sharing intelligent objects from the model
- The need for increasingly sophisticated data management at the building object level – Pioneering model server technology is only now being developed to help address issues which surface when multi-disciplinary design teams try to adopt a single BIM such as object versioning, object-level locking and real-time, multi-user access
- A contradiction in work process when using a single detailed BIM to try to represent a number of the alternative design schemes under consideration – While parametrically defined building objects can quickly be recreated based on the input of selected dimensions and properties, the need to maintain separate BIM models for different design alternatives is prohibitive
- Managing "what if" scenarios for engineering design – Using a single BIM model for building performance modeling (i.e. energy analysis, sun/shade studies, egress simulation, etc.) does not provide the flexibility needed by consulting engineers to conduct a multitude of "what if" scenarios to study alternate approaches and to optimize design alternatives in order to maximize energy efficiency, ensure fire and life safety compliance, achieve structural integrity at minimum cost, etc.
- The expectation that everyone on the project team will adopt one BIM system – Project teams comprise a collection of different companies, each of which has their own preferred and trusted software applications for design and analysis. It is very rare that a single technology is being used on any one building project between different companies and/or across all phases of the project lifecycle

Although the particulars of each firm's experience with BIM differs, the experience of HOK's London office on the Bart's and The London Hospital projects is typical of nearly all of the firms we have talked to – significant progress in changing work practices to embrace a model-based design process and success in generating coordinated documents, coupled with frustrating limitations. *"BIM has had a tremendous, positive impact within our immediate project team on our ability to design, visualize and communicate the essence of a complex facility to a broad audience. It has helped us solve a number of problems involving challenging geometry on a highly-constrained urban site. Our structural engineers have had great success in sharing their concrete and steel 3D object models with us, which we integrate into our own architectural model and use in our 1:50 plan sheets, thus resolving one main issue of BIM collaboration through interoperability of data sharing. We continue, however, to face technological restraints in sharing data with the design team and supply chain. For example, analysis software for wind, shadow and day lighting simulation require a much simpler model to work from; ideally, these studies should be possible from the single model that we have built, without the necessity to draw additional simplified models for analysis purposes. Additionally, design file sizes and the complexity of data management on BIM projects are a tremendous challenge to coordinate and distribute effectively",* says Miles Walker, the CAD Manager for HOK's London Office and for the Bart's and The London Hospital projects.

Reality Check #3 – BIM as Only One of Many Purpose-Built Models

While BIM is proving itself as a very powerful architectural design and coordination tool, research conducted by Newforma tells us that the limitations identified above represent recurring difficulties in the use of BIM for project-wide design and documentation. Our subsequent analysis shows that rather than being dependent on a single building model, project team members typically rely on a number of purpose-built models including:

- 3D conceptual design model (created using SketchUp for example)
- Detailed geometric design model (created using Bentley Architecture, Structural, and HVAC products for example)
- Structural finite element analysis model (created using STAAD for example)
- Structural steel fabrication model (created using Tekla's Xsteel for example)
- Design coordination model (assembled from multiple sources of design information via NavisWorks, for example)
- Construction planning and sequencing model (created using Graphisoft's Virtual Construction solutions for example)
- Hospital Equipment inventory model (creating using Codebook for example)
- Energy analysis model (created using DOE-2 or Energy Plus for example)
- Fire/life safety and egress model (created using IES "virtual building environment" for example)
- Cost model (created using Timberline for example)
- Resource planning model (created using Primavera for example)

Each of these design applications and the purpose-built model they create and manage has been highly optimized for the precise needs of the discipline/trade involved, and for the specific project process they support.

Even with the advent and adoption of BIM, what is really happening industry-wide is the use of a growing number of purpose-built models. This trend is being driven by a number of different factors; the availability of more sophisticated building systems; higher expectations for building performance and energy efficiency; new fabrication methods; an increased awareness by owners to make decisions based upon building lifecycle costs versus initial capital cost; increasing reliance on technology to perform more detailed analysis and computed designs.

For example, *"One of the key ingredients to introducing Environmentally Sustainable Design (ESD) principles into design is technology – specifically the use of building simulation applications performing a variety of analyses with relevance to technology of Building Performance Modeling (BPM). The use of BIM is more aligned to building design and documentation production rather than building performance modeling. Typically, those creating the BIM have little knowledge of BPM and hence most of the BIM data structures are not suitable to provide the 3D spatial and connectivity information required by BPM,"* explains Don McLean, CEO of Integrated Environmental Solutions, Inc.

In our research, we have found the same kinds of issues arise between phases of the AEC project process, such as between the design and construction phases. Initially, due to reluctance on the part of the architect to share their models out of liability concerns, some innovative general contractors began developing their own construction phase models. Now, these same contractors routinely develop their own construction phase models, because architects and contractors idealize/model a building in completely different ways. Contractors find the greatest value from a construction model that they create themselves, specifically for their purposes in managing the construction process.

It is not reasonable to expect that the use of BIM should dictate that individual members of the project team abandon the tools they trust, and that are highly optimized to support their individual work processes. It is the project information being created and maintained across all of these purpose-built models which, in aggregate, fully describes everything that is known about a project. BIM is an important subset. Intelligent objects are a key enabler, but the critical missing ingredient is "interoperability" – the ability for each of these purpose-built models to interact and be coordinated as a consistent representation of the same building.

Our research indicates that BIM is best viewed as just one of many purpose-built models, as a "source" of information about the building, rather than being viewed as a "destination" for every item of information about the project. BIM is primarily a geometric model with the advantage that its parametric variables and associated non-graphic properties provide richer transfer of building information to/from related purpose-built models used for design analysis, building performance and simulation.

Reality Check #5 – BIM and Interoperability
The cost burden to the U.S. construction industry due to inadequate interoperability among computer-aided design, engineering, and software systems is described in the August 2004 National Institute of Standards and Technology (NIST) report entitled "Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry," (The full report is available for download from the NIST website).

In addition, the Architectural/Engineering Productivity Committee of The Construction Users Roundtable (CURT), in analyzing why building owners regularly experience project schedule and cost overruns determined that the project delivery process is fraught by lack of cooperation and poor information sharing in its report entitled, "Collaboration, Integrated Information and the Project Lifecycle in Building Design, Construction and Operation," (The full report is available for purchase by non-members from the publications listed on the CURT website).

Interoperability – the sharing of information between these different models – is critical to the success of BIM. Demanding support for open data standards and non-proprietary access to BIM data is an urgent priority for the industry if we are to avoid the inefficiencies and recurring inaccuracies of data re-entry. Interoperability will allow the re-use of project data which has already been created and thus ensure consistency between each of these models as different representations of the same building. Interoperability will also allow the comparison and validation of purpose-built models in support of faster revision cycles and the iterative nature of the design process. Consistent and accurate data accessible on demand by the entire project team will contribute significantly to mitigating project schedule and cost over-runs.

Conclusion
BIM is certainly viable and offers many realizable advantages over CAD. However, it is the ability to share the intelligent building information being generated in a BIM (whichever approach you choose) to/from/between the other purpose-built models, that is critically important.

Traditional approaches to sharing project information via file exchange using formats such as .dxf, .dwf, .dwg and .pdf do not transfer the appropriate levels of object intelligence from one model to another. New approaches which strive to address the need to exchange more intelligent project data include IFC-based model exchange (i.e. to transfer objects, their relationships and associated property sets), 3D DWF from Autodesk and 3D support in PDF from Adobe.

Based on our research, we believe that the ubiquity of XML as a protocol for transferring sub-sets or "packets" of relevant project information is a key opportunity to achieving interoperability across such a large and fragmented industry.

Perhaps the best example of this is the Green Building XML (gbXML) schema. Developed by Geopraxis, gbXML provides a standard exchange mechanism between sources of building model information (including Architectural Desktop, REVIT, and ArchiCAD), and energy analysis and simulation products (including Green Building Studio, Energy Plus, and TRACE). GbXML has grown to support six different sources of BIM data and nine different energy analysis/simulation products. The success of gbXML stems from its focus on a clearly defined, high-value process that it seeks to enable, its use of an open data standards approach, and the availability of software development tools to facilitate adoption.

BIM has an important role in creating and coordinating objects as a source of intelligent information about a building. BIM data must co-exist with a number of purpose-built models all of which are essential in defining the detailed knowledge of a project. A pragmatic and achievable basis for information sharing between these different models is essential to achieve the urgent need for better interoperability between disciplines and software applications across the industry.

About the Authors

Ian Howell is Chief Executive Officer of Newforma, an Australian architect, a co-founder and current board member of the International Alliance for Interoperability, and has extensive experience in applied technology in the building industry. Ian has a long standing association with building modeling, dating back to being the Australian distributor for RUCAPS and Sonata, as early incarnations of a building modeling approach to CAD. As a director at Autodesk, Ian managed the team responsible for the first two releases of ADT prior to becoming a Vice President at Citadon. Ian can be contacted by email at ihowell@newforma.com.

Bob Batcheler is Vice President of Industry Marketing at Newforma, a qualified civil engineer with broad project experience, and while at Softdesk and Autodesk, served in many roles, including Director of Product Management for the AutoCAD 2004, and Autodesk Architectural Desktop 2004 products. Bob can be contacted via email at bbatcheler@newforma.com.

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