Building Information Modeling

References

Introduction
The complexity and rapidly paced development of today's projects are challenging the industry to find new, innovative approaches to project delivery. Building Information Modeling (BIM) is emerging as a high-tech, process transformational method to address some of these challenges. BIM methodology enables owners, consultants, and other stakeholders to visualize and understand evolving designs and collaboration issues as never before. The information-packed digital assets produced during a BIM-based project have the potential to transform the way supply-chain partners work together to improve the design and construction process by enabling early identification and removal of problems. This is resulting in cost and schedule benefits and assisting health care projects to avoid costly delays. In addition to the benefits to design and construction, the digital assets associated with BIM offer potential to improve the facility management and operations process long after occupancy begins.

The traditional process used in the design and construction of facilities relies heavily on the production of paper-based and electronic drawings, which typically illustrate two-dimensional (2D) views, plans, sections, etc., of the various discipline components associated with the project. While these 2D drawings attempt to accurately define systems and components, they often fall short of capturing the full level of detail, coordination, and information that is needed at some point in the delivery process. They are time-consuming to produce, difficult to fully comprehend, and, because of their 2D nature, cannot be fully utilized by other parties in the supply chain for the project.

The BIM delivery methodology uses accurate three-dimensional (3D) digital models that are assembled by architects, engineers, designers, and fabricators. These 3D models are much easier for project stakeholders to comprehend because of their visual characteristics. The old adage “a picture is worth a thousand words” has been proven time and again in the BIM environment. While the visual nature of the 3D models promotes improved understanding and collaboration in design, more important, it serves as a robust carrier for detailed information about each specific discipline component in the model. This information can be accessed by those directly involved in the design process, and later by other parties involved in the project delivery process. The information contained in these BIM models is the source of the true value of BIM, for it is precisely this data that can be used downstream to improve production efficiency and quality.

Typically, 2D drawings are still used in the BIM process, but unlike the traditional drawing-centric approach to design, the drawings created in the BIM process are extracted from the 3D models. Since the 3D models can be better coordinated within and among the design disciplines, this results in a more accurate set of drawings available to the project delivery process. If the model is right, the drawings are right. The 3D visual nature of the BIM models makes it easier to get it right.

There are several technology manufacturers of BIM software platforms for this industry. A few of the more popular platforms include offerings from AutoDesk, Bentley, Graphisoft, CATIA, and Tekla. While these platforms do not always seamlessly share model information among themselves, there are interchange standard development projects throughout the industry that are attempting to address this interoperability issue. Chief among these is the Industry Foundation Class (IFC) standards development effort sponsored by buildingSMART International. BuildingSMART is an international membership organization with representation in North America, Europe, Asia, and Australasia, which brings together architects, engineers, constructors, product manufacturers, and facilities managers, along with software vendors and constructors. In the interim, technologies such as the NavisWorks system from AutoDesk make it possible to combine the geometry from BIM models developed in disparate BIM platforms to provide the project with a single integrated virtual model that can be used to inform the design and coordinate the discipline components.

What Is "BIM"?
Compared to the traditional approach for designing and building projects, BIM offers many advantages in the areas of multidiscipline collaboration, cost and schedule reduction, improved understanding of the project, and improved constructability of the design. Unlike the drawing-centric approach used by the traditional delivery process, BIM enables project participants to access the various digital models throughout the design process...
without having to wait for paper drawings to be produced and delivered. This provides a multidiscipline view of
the project that can be shared with all participants early in the process and continuously throughout design and
construction. Experience shows that collaborating in this fashion produces breakthrough results that are not
possible using drawings alone. Higher-order collaboration among project participants and better understanding
of the design through visualization are just two of the immediate and impressive benefits the BIM approach will
bring. These two factors alone will result in a substantial reduction in requests for information (RFIs) and field
rework, which will, in turn, lead to improvements in project schedule and cost reliability.

In the BIM delivery process, each design consultant generally develops its own specific BIM 3D model.
Typically, several BIM models will be created for the project. The architect will develop a BIM model, as will
the structural engineer, civil engineer, and the mechanical, electrical, and plumbing (MEP) engineers, etc.
Depending on the size and complexity of the project, each of the consultants may elect to produce several BIM
models for his or her part of the design by partitioning the project for work and system performance issues.
These models are developed using BIM software platform provided by technology manufacturers such as
AutoDesk or Bentley. Although developed separately by each discipline, the individual models can be virtually
combined at any point in the process to support an enhanced form of digital coordination and design review.
Generally the earlier in the process this type of coordination occurs, the fewer problems ultimately emerge.
Figures 1 through 3 illustrate typical discipline models created by a project's lead consultants in different BIM
platforms. As is evident from the illustrations, each discipline model can stand on its own and contains the
detailed geometry and other information necessary to describe the specific design.

![Figure 1. Structural BIM Model](created using REVIT Structure by AutoDesk)
During the actual design process, the BIM models are used to coordinate the discipline designs to detect and rectify interfering components. This process is accomplished by creating a single, combined, virtual 3D model containing all of the individual discipline's BIM models using technology such as NavisWorks from AutoDesk. This combined virtual model can then be used to visually coordinate the design and programmatically check for interferences. This new type of coordination can largely be accomplished before any drawings are produced, thus saving time and money while improving the team’s ability to understand the progression of design activities and identify problem areas early on. Experience on projects leveraging this approach shows that this type of coordination will often lead to the identification of "functional" clashes in the design, in addition to "physical" clashes between components. The identification of these functional issues is made possible by the detailed virtual mock-up of the design that BIM permits early in the process.

Figure 4 illustrates such a combined virtual model where the BIM models from the architect, structural engineer, and MEP engineer have combined to provide a comprehensive virtual "mock-up" of the design in progress.
Project stakeholders outside of the immediate design consultants can benefit immensely from this process, as their ability to inform the design early on is greatly enhanced. While 2D drawings are still produced during a BIM delivery process, they are extracted from the model and need not be relied upon as the sole means of communicating the design early in the process. Since these drawings are extracted from the BIM models, their production can be more cost efficient, timely, and of better quality than those produced using the traditional delivery process. Project participants gain a better understanding of the design and how the various disciplines function together through visualization. As shown in the illustrations below, a 3D image is much more user friendly than traditional 2D drawings when it comes to understanding the design concept and how things work together. As the presentation venue moves from the 3D model shown in Figure 5 to the 2D drawing shown in Figure 7, it is evident that the level of overall design comprehension is degraded for most parties. Using the BIM models, various software review products can be used to provide virtual 'walk thurs' of the facility. Users can view the model(s) from any location, any angle, any perspective. This capability serves to promote enhanced understanding of the design. Experience has shown that the ability to understand the design more completely, at all stages of the project, using this powerful means of visualization is one of the greatest benefits of the BIM process at the current state of the art.
Although its extraction from the BIM model makes the drawing shown in Figure 7 more accurate than its traditional 2D counterpart, note how much more difficult it is to fully assess the overall system when trying to visualize from a set of 2D drawings showing only plans, elevations, sections, and individual details.

**Improved Consistency and Error Reduction**

As a data-centric process, the BIM-based delivery approach employs consistent digital representations of each discipline’s work product or data model. These data models are in turn used to generate many of the required deliverables for the project, such as drawings, specifications, material quantities, and visual design reviews. Drawings are extracted directly from the BIM model, then annotated to suit particular requirements.
This extraction process ensures that whatever is represented in the model is represented accurately on the drawings. This new relationship between data and drawings can significantly reduce errors, inconsistencies, and uncertainty in drawings that are used by each discipline to inform the rest of the project’s supply chain.

![Figure 8. BIM Is a Data-Centric Design Process](Central Digital Model Drives Production of Project Deliverables)

As an example of the improvements in consistency of information transferred between design and construction, consider the exchange of information between the engineer and fabricator. In the traditional drawing-centric process, this transfer is normally accomplished solely by means of 2D drawings, which often do not contain all of the detailed or relevant information a fabricator may require to fully understand the design of a component or connection details between components. Using BIM, the fabricator can take advantage of a more complete and accurate representation of the structure. The fabricator can visualize the entire system, which eliminates the need to rely solely on a set of 2D drawings that may not contain sufficient detail to answer a fabricator's particular questions.

As an additional benefit, material quantities contained in the BIM design model can now be accessed directly by the fabricator and used to check quantity estimates. In cases where the design model has been fully detailed, it may even be possible for the fabricator to use the model directly and extend its detail as appropriate for the fabricator's use. The illustrations below provide some insight as to the level of detail that can be accommodated in the 3D BIM models.

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Building Information Modeling

Page 8

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It is important to note, however, that in addition to the keen visual representation of the system a BIM model provides, each component can contain a robust selection of information that is addressable by third parties, such as material quantity, material specification, component location, and member forces required for connection design.

If both parties, the engineer and the fabricator, have achieved high levels of sophistication in working in the BIM environment, it may be possible to work directly from the BIM model, thus eliminating the necessity of producing, reviewing, modifying, and distributing shop drawings that communicate the fabricator’s understanding of the design to the engineer of record for approval. The elimination, or streamlining, of this effort alone can result in huge cost and time savings on projects.

This enhanced level of detail and underlying information inherent in BIM models has proven instrumental in reducing errors and RFIs in the process that invariably slowed the delivery process and made it more costly.
Project BIM Coordination, Administration, and Systems Integration

An important component of the BIM-based delivery process is the provision for a new and innovative technology-based collaboration process that supports the design by leveraging the information packaged in the individual BIM models produced by the consultants and contractors. This process applies a managed approach to interference detection and change control by developing a comprehensive framework for clash detection and subsequent management of interference resolution issues. Individual discipline models created by compatible BIM platforms are brought together in a single virtual model that can then be used by the team to review the design. Interference between components can be identified and fixed before any drawings are produced. Most of the commercially available software products that perform this type of interference detection do so programmatically using the geometry defined in the models. The interfering components are automatically identified based on interference detection criteria set by the user. There is no need for a user to visually identify components that interfere since the software platform will perform this function. This is of course a tremendous advantage, promoting the efficiency and effectiveness of this process.

The old cliché “a picture is worth a thousand words” rings true as new high-tech design review sessions are orchestrated around the digital models. When architecture, structure, civil, and mechanical elements combine in one environment, the design team has the ability to innovate more effectively. Issues that arose only in the field are now addressed early in the design process, where change and improvement can be cost-effectively administered. This new collaboration technique is producing breakthrough results compared with the traditional process, where many of these issues were discovered only in the field, at the most expensive possible point for remediation. While the process is robust, it is not intended to replace the traditional quality control process used by the project, participating consultants, and contractors, but rather to enhance the team’s ability to visualize the design and detect coordination issues early.

Figure 11 illustrates a typical interference, or design clash, that can easily be detected using the new high-tech collaboration process. The figure shows an HVAC duct hitting diagonal structural braces and gusset plates. The traditional process of reviewing stacks of 2D drawings by light table overlay is a labor-intensive process and is significantly encumbered by the complexity and lack of detail in the 2D environment. The detailed geometry available in 3D BIM models makes this type of clash detection relatively straightforward and automatic, assuming the required level of detail has been built into the discipline models.
between individual models can be both analyzed and visualized. This is particularly challenging when the models are developed using different technology platforms. Given the current state of various data interoperability standards among today’s leading 3D vendors, the ability to combine 3D models created with different systems is key.

One available solution uses the NavisWorks Technology Framework and applies a managed approach to interference detection and change control. This process and technology can provide a suitable framework for clash detection and subsequent management of the interference resolution issues. The approach requires that the parties participating in the collaboration effort use a modeling technology that is compatible with the NavisWorks system. Many of the systems used today for 3D modeling of architectural, structural, and mechanical equipment components are compatible with the NavisWorks system. This process is not meant to replace the traditional quality control process used by the project and participating consultants, but should enhance the ability to visualize the design and detect interference between discipline components. Another solution for interference detection is provided by the Solibri Model Checker software. This platform leverages the IFC standards mentioned earlier to detect and report on interferences in building components by discipline, type, severity, and location. Regardless of the software platform used for this function, the ability to programmatically detect interferences in discipline components early, and throughout, the design and construction process is a very valuable capability with a significant return on investment.

To be truly effective, this new coordination/collaboration process should be managed on the project by a new role, referred to for purposes of this discussion as a project collaboration administrator (PCA). This role is often known by other names such as BIM Model Manager, Model Owner, and Project BIM Coordinator. Working under the direction of the project manager, the PCA is responsible for collecting and processing 3D models from the various participants involved in the collaboration process. This provides an improved level of coordination and a model management process within the limits of the existing technology. The project manager retains responsibility for deciding the final path for resolving detected interferences. The PCA’s role is to facilitate and support the project manager’s decision process. A typical placement for the PCA in the project organizational structure is shown in Figure 13.
The PCA relies on provision of 3D models from the various project consultants or contractors. These models are then combined into a single multidiscipline model and checked for interfering components.

The scope of services provided by the PCA is designed to assist the project manager in the administration of the collaboration process relative to interference detection and visualization of the single multidiscipline model. Each consultant, or contractor, participating in the process is responsible for maintaining his or her individual model(s) and making whatever modifications result from PM’s decisions to resolve interferences. While the PCA will generally manage the single 3D multidiscipline NavisWorks model, the PCA does not have responsibility for directly modifying the individual consultant or contractor’s 3D model in any way.

Simulation-Based Modeling

Use of BIM on the project enables the development of 4D models that incorporate the elements of time and schedule into the existing 3D BIM models. These 4D models will expand the value of the 3D models and project scheduling systems by improving understanding and collaboration for all project participants. Some of the key attributes associated with these models will improve site planning by enabling “what if” scenarios to test and improve plans. Simulations of installation conflicts, design clashes, and workflow management can be performed before work begins on site. Construction sequences can be simulated to facilitate quick and effective decision making by the contractor, design team, and owner. Schedule sequences can be performed continuously for an overview, or stepped through to show the project at particular points in time; because these sequences are linked to actual project construction schedules, they provide context for decision making. The same technology can be used to resource space planning scenarios and evaluation of medical equipment options. Real-time navigation is supported during the simulations to enhance exploration.

In today’s project environment, 4D models have typically been used to illustrate construction sequencing activity. The process is relatively straightforward so long as the BIM models have been constructed with sufficient granularity to support linking to the construction activity schedule. Creating a 4D model requires linking individual elements, or groups of elements, in a discipline’s BIM model with discrete, date-driven construction activities that are generally contained in the contractor’s construction schedule. The 4D model creator uses a simple process to link model elements with construction activity line items in the construction schedule. Once completed, this model can be played back to simulate the actual occurrence of events visually. Current 4D creation technology can support a wide variety of BIM platforms and scheduling platforms, including Microsoft Project and Primavera SureTrack.

In the following sequence of illustrations we can see the progression of the construction of a multilevel pedestrian bridge connecting a new facility to existing facilities and spanning a highly used traffic corridor. This model was produced using the Navisworks Timeliner system by linking it to the Primavera SureTrack schedule. There are other 4D simulation technologies in the market including one from Synchro.
Figure 14. Permanent Foundations and Temporary Falsework in Place for Erection of Circular Pedestrian Bridge. Initial Bridge Section Set

Figure 15. Second Bridge Section Erected, Steel Cantilevers Over Roadway
Figure 16. Third Bridge Section Erected

Figure 17. Interconnecting Bridge Section Set
The ability to visualize the construction sequence in the actual context of the site provides the design team, owners, contractors, municipalities, regulatory agencies, and other interested parties with a bird's-eye view of the process, simplifying their understanding of the events to occur. In many instances this improved understanding can facilitate the decision-making process often required when scheduling work in logistically challenging environments. It provides visualization that results in a more intuitive understanding of the process.

Facility Management Opportunities
Since the underlying models in a BIM-delivered project are digital in nature, each component in the model can contain a rich association of data about its own attributes, such as size, weight, material properties, cost, specifications, assembly diagrams, maintenance procedures, and schedules. Use of BIM can lay the groundwork for the creation of derivative facility management models by leveraging the BIM design models produced by the various consultants. The facility management model can be broadened over time to include
other attributes, such as links to specific drawings, documents, manuals, maintenance procedures, and schedules needed for the long-term operation of the facility, useful to operations managers and planners. Spatial attributes of the BIM model can be used by facility managers to improve the space planning or tenant management process by providing fast, accurate, and automated access to area definitions. Early identification of the facility management requirements will assist in the development of specifications and requirements for the design and construction models.

A current impediment to full utilization of BIM for facility management is the lack of interoperability among the various BIM platforms likely to be used by the consultants, contractors, and subcontractors on the project. Few owners, if any, have the resources to acquire, train, and sustain a staff of personnel skilled in an array of BIM technologies. What the industry needs is a single-source facility management system that is able to process BIM models from different sources, much like NavisWorks or Solibri does in the collaboration space. The IFC standards mentioned earlier will be helpful in achieving this goal. In addition to the technical obstacles, BIM models developed during the design and construction phase of the project must be properly outfitted with the information necessary to support useful facility management operations. Closing this gap will require significant cooperation between the owner's teams and the designers and constructors.

The increased use of BIM in design and construction should logically lead to a demand from owners for BIM facility models that can be used to manage the facility during its life cycle. There are some examples of owners who are pushing the envelope in this regard; for example, the U.S. General Services Administration (GSA) now requires the delivery of spatial program information from building information models for major projects (http://www.gsa.gov/bim). The National Institute of Building Sciences (NIBS) formed a committee in early 2006 to create a National Building Information Model Standard to provide a common model for describing facility information (http://www.nibs.org), and the Construction Users Roundtable has been encouraging owners to transform their delivery process by leveraging BIM in the design, construction, and life cycle management of their facilities (www.curt.org). The American Institute of Architects (AIA) has issued a Position Statement on Interoperability (http://architosh.com/2010/02/aia-board-of-directors-approves-statement-on-interoperability/), which states in part:

“The AIA believes that all industry-supporting software must facilitate, not inhibit, project planning, design, construction, commissioning and life-cycle management. This software must support non-proprietary, open standards for auditable information exchange and allow for the confident information exchange across applications and across time.... The AIA encourages its members and other industry organizations to assume a leadership role in the ongoing development of open standards.”

Many other organizations are adopting BIM in their process, including the United States Coast Guard, Veterans Administration, state agencies, and others.

When viewed holistically, it is obvious that BIM-based project delivery offers a new, innovative, and beneficial approach to project delivery. Several case studies, including significant projects conducted by the GSA (http://www.gsa.gov/bim), have proven the benefits. To capitalize on the process and technology, it is necessary to deploy the BIM approach early in the project, get the major consultants and contractor on board, and ensure that the contract documents and BIM project objectives are clearly defined and understood. As interest in the delivery process continues to grow, projects that use this approach will continue to benefit.

**Best Practices in BIM Execution**

There are several proven best practices related to the use of BIM-based project delivery. First and foremost, the decision to execute using BIM processes should be made early in the project to maximize its benefits. While BIM modeling techniques can be initiated at any stage in the project, even after the completion of construction drawings, the greatest benefit is achieved by starting early in the process. All the major consultants, contractors, and subcontractors should be enrolled in the process. As a minimum, the project should assemble the BIM using digital models from the architect, structural engineer, civil engineer, MEP, and related subcontractors. Where possible during the design phase, the contractor should participate in the digital review process to improve the design’s overall constructability. Such participation will prove valuable in evolving the design BIM models into relevant construction models to be used later by the contractor.

A key issue to consider in establishing a project for a BIM-based delivery is development of contract requirements for the project’s specific BIM objectives. The contracts should be developed to include BIM specifications, including terms and specific requirements for production of the building information models. Language specific to the technology to be used, the disciplines requiring participation, and the
discipline-specific scope of work should be included. The reader is advised to review reference material on BIM contract issues found in the sample Electronic Communications Protocol Addendum in ConsensusDOCS 200.2 (www.consensusdocs.org). Another useful reference dealing with BIM model scoping definition can be found in the AIA E202-2008 document Building Information Modeling Protocol Exhibit (www.aiacontractdocuments.org).

One of the key areas for consideration is the definition of the actual scope of discipline components to be modeled. While effective coordination and clash detection can be performed only on modeled elements, effort and cost obviously are associated with these modeling activities. The level of detail to be provided by each discipline must be determined, considering both the amount of effort required to produce the digital detail and the return on investment from such production. A clear understanding of model scope will avoid issues associated with design decisions based on model information that is not necessarily complete. Of course, many interferences will be discovered, and avoided, using models that have even a basic level of detail. The following list illustrates the types of discipline components commonly found in BIM models today.

**Architecture BIM Model**

- Interior and exterior walls shown as composite families with individual materials or elements identified in the wall structure.
- Ceilings created with ceiling heights and materials or elements identified.
- Doors created with sizes of panels and frames.
- Exterior windows with opening sizes indicated. No materials or frame section sizes.
- Curtain walls with frame sizes indicated but may not be “extractable” for cost and energy calculations. Glass types indicated.
- Roof created as composite families with individual materials and elements identified. Complicated roof structures may be created with generic models.
- Casework or millwork: Shapes such as toe kicks, door swings, shelves, and drawers will be indicated.
- Light fixtures: The type of fixture, such as direct or indirect 2x4, parabolic 2x2, or pendant, indicated as part of the family parameters.
- Stairs and ramps: Sizes and basic stair materials (concrete or steel). No finishes.
- Elevators: Sizes and weights indicated. No electrical information.
- Wall protection, toilet partitions, fire extinguisher cabinets, with sizes included.
- Louvers: Sizes indicated. Blade type and size not included.
- Generally no interior finishes included in the model.
- Models of flooring finishes such as terrazzo and ceramic tile may not be included. Slab depressions should be modeled.
- Some complex geometries may be modeled masses with no materials identified.

**Structural BIM Model**

- All cast-in-place concrete, including formed mechanical penetrations and openings that require header beams.
- MEP openings that will be core drilled shall be handled with typical details. However, if penetrations are required through beams, then they are included in the model.
- Edges of all slabs and penetrations of structural systems.
- Slab depressions for elevated slabs.
- All primary and secondary structural steel members, including standard steel member sizes, gusset plates adjacent to architectural openings, braces, equipment supports, and kickers.
- Metal and concrete decks will be modeled as to their overall thickness. Reinforcing steel is not generally modeled.
- Embeds not generally modeled.
- Bolts, clip angles, etc., not generally modeled.
- Slab camber generally not modeled.
- Chamfers at corners not modeled.

**MEP BIM Model**

- Large mechanical equipment such as pumps, chillers, boilers, and heat exchangers are typically modeled from manufacturer cut sheets with connection points for duct or pipe.
- All ductwork.
- All pipes 2 inches and larger are modeled, routed, and coordinated.
- Air terminals and terminal boxes are located and coordinated.
- Dampers, valves, and thermostats are typically indicated with 2D schematic symbols.
- Waste pipes are typically sloped and coordinated.
- Sprinkler heads and fire protection equipment are typically modeled.
- Electrical equipment such as switch gear, panels, substations, generators are modeled.
- Conduit feeders greater than 2 inches are typically modeled and coordinated.

As the BIM platform technology becomes more mature and robust with respect to component catalogs, and the users of BIM models become more sophisticated in their application of BIM to their internal processes, it will become commonplace for disciplines to model more detail because it will be more efficient within the BIM platform than using 2D drawings. Additional information will be added to components, including accurate material specification information when it can be used effectively by downstream parties. Presently all projects must consider how much effort to expend in the development of model details and the value such detail provides in supporting the BIM objectives of the project.

An additional area of focus during the contracting stage should be devoted to model ownership, more specifically, the definition of the permissible and intended uses for the models. One of the attractive advantages of BIM is the potential for downstream users to leverage digital information contained in the models. The accuracy and availability of this information will lead to interest by many in gaining access. The extent to which project participants can rely on models for specific uses will be defined. This is an emerging area in the BIM environment, and there are not many tried-and-true templates available for general use. Most projects are customizing contract language to handle this issue, but rely on the references cited above, as well as others, as they emerge in this fast-paced and changing environment.

Finally, to ensure that the project benefits from an advanced level of collaboration, it is vital that a specification be explicitly developed for project coordination that adequately addresses BIM process coordination and collision detection, as well as required reporting among all disciplines. The specification should identify the detailed processes, roles, and responsibilities of team members used in design review and coordination meetings, as well the process to be used for identifying, communicating, and tracking issue resolution. At a minimum, this specification should address the following areas:

- Model design review schedule
- Required data transfer protocols
- Appropriate 3D modeling guidelines
- Identification and classification of model freeze points as appropriate
- Component prioritization schemes as required
- Specifications for model synchronization log
- Roles and responsibilities of collaboration partners
- Format and content of graphic and text-based interference reports
- If desired, 4D model specification incorporating key scheduling data
- Required BIM technology, servers, storage, backup services, Internet connection, and web hosting services
- BIM model ownership, including resolution of intellectual property issues

References

**Relevant Codes and Standards**

- BIM Overall Scope, Coverage of Version 1.0.
- Construction Operations Building Information Exchange (COBIE) Project.
- Inter-agency Federal Asset Classification Team (IFACT) Project Fact Sheet (PDF 92 KB).
- International Alliance for Interoperability, IFC's (ISO PAS 16739).
- United States National CAD Standard v 4.0.

**Reports/Guidelines/Publications**

- AEC Bytes—progressive information about BIM and CAD issues.
- AiArchitect.
- AIA Integrated Project Delivery.
- All Things BIM.
- "BIM 2011: A Five-Year Forecast".
- Cadalyst-online and print magazine covering AEC, MCAD, and GIS.
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Roe, Andrew. "Building Digitally Provides Schedule, Cost Efficiencies. 4D CAD is expensive but becomes more widely available." News from DPR, Engineering News-Record, February 2002.


Books and Criteria


Fukai, Dennis. Building Simple: Building an Information Model. Insightbuilders, 2006. A primer for those trying to get their arms around the basic concept but does not go far enough into where BIM can go; primarily oriented toward construction contractors.


Kim, W. Chan, and Renee Mauborgne. Blue Ocean Strategy. Harvard Business School Press, 2005. Points out that instead of competing against your peers, you are far better off finding the "blue ocean" or new areas in which to grow a business. BIM world is a "target rich environment" of opportunity for all.

