BUILDING INFORMATION MODELING

By Nick Papadopoulos

At the time of this writing (2014), Building Information Modeling (BIM) continues to be in the early stages of industry-wide adoption. While some firms have taken a leadership role in exploring and applying BIM for years, the architecture, engineering and construction (AEC) industry has not agreed on the definition of BIM, the benefit of BIM, the return on investing in BIM, or the best means and methods to implement BIM. Clients (project and facility owners) also vary greatly in the demand, usage and benefits of BIM.

The design community has been striving to leverage BIM for many years with most benefits related to the production of coordinated construction documents. Design teams continue to use a variety of file formats and often use different tools. Contractors have been using BIM in support of sales and marketing efforts, and in the field to support logistics, planning, and coordination. A recent McGraw Hill Construction SmartMarket Report on BIM identified that over 74% of contractors in North America utilize BIM in their project delivery processes. With the exception of high-tech specialists, the typical cost estimator is not often exposed to the benefits of BIM, and infrequently influences BIM processes and deliverables. As BIM adoption increases, its impact will be felt more and more by the cost estimating community.

This paper is intended to help the professional cost estimator understand his or her role in the ever-changing world of BIM.

BIM: A Definition

BIM is an evolving concept or methodology, which makes it difficult to settle on a single, simple definition. Attempting to define BIM would surely omit some important aspect to one or more groups as the industry is still grappling with the fundamentals. BIM definitions often lead to philosophical and idealistic debates, and for some, it's right up there with religion and politics. Thus, we'll defer to a well-established association for a current, but not simple, definition.

The BuildingSMART Alliance (www.buildingsmartalliance.org) is a widely recognized standards organization that operates as a council of the independent nonprofit National Institute of Building Sciences (NIBS).

The BuildingSMART Alliance builds upon work efforts of the National Building Information Modeling Standards (NBIMS) Project Committee. The NBIMS Project Committee defines BIM as follows:

> *Building Information Modeling (BIM) is a digital representation of physical and functional characteristics of a facility. A BIM is a shared knowledge resource for information about a facility forming a reliable basis for decisions during its life-cycle; defined as existing from earliest conception to demolition.*
>
> *A basic premise of BIM is collaboration by different stakeholders at different phases of the life cycle of a facility to insert, extract, update or modify information in the BIM to support and reflect the roles of that stakeholder.*
>
> *The US National BIM Standard will promote the business requirements that BIM and BIM interchanges are based on:*

- *a shared digital representation,*
- *that the information contained in the model be interoperable (i.e.: allow computer to computer exchanges), and*
- *the exchange be based on open standards,*
- *the requirements for exchange must be capable of being defined in contract language.*

The BuildingSMART Alliance director Deke Smith offers this definition:

"There are many definitions for a BIM... Many people associate BIM with a 3D model of an architectural design, but it can be so much more than that. A BIM model is a placeholder for the information about a building or a facility. It can include also ductwork, electrical installation, fire protection, occupancy, energy consumption, CO2 emissions or whatever information you need to collect regarding a site or a building.

A BIM model does not even need to have geometry, only information, and still be a BIM. This also means that BIM is the same as a 3D CAD model and vice versa. In fact, many BIM building projects do not start with a model made by a CAD system, but from information about a client's requirements for a project long before anything about geometry (like shape, number of stories, floor plan etc.) has been created. This collection of information is also a BIM and can later be fed into a BIM Authoring tool (i.e. Architectural CAD/BIM system) to enrich the model with geometry and design. How this is done in day-to-day projects is more about the process than about technology and formats."

Dimensions of BIM

Building Information Modeling (BIM) means many things, depending on one's perspective. Right or wrong, BIM is often described through various 'dimensions' to assist in categorizing its aspects and usage. (Note: The use of "Ds" to describe BIM is a topic of considerable debate).

Building off conventional or 'flat' two-dimensional (2D) construction documents, BIM dimensions include the following:

- 3D – Something seen in three physical dimensions. The model or models represent the building as a collection of objects or elements including footings, slabs, columns, doors, windows, ducts, piping, equipment and fixtures. For example, the models may include civil, structural, architectural, mechanical, electrical, plumbing, fire protection, and control system design elements.
- 4D – The combination of time and geometry (3D). The goal of this dimension can result in a construction sequence animation where participants can visualize the completion of building objects at a certain point in the construction schedule. Or the result can be a complex, resource-based schedule based on quantities derived from the 3D geometry.
- 5D – The combination of cost to geometry and time. The goal of this dimension is to produce a cost estimate or budget including all costs (e.g. labor, material, subcontract, and equipment) associated with each element. The quality of the estimate is based on the quantities derived from the Level of Development (LOD) and Level of Detail (LoD) provided by the 3D model. That is, if the model geometry and information isn't reliable (LOD) or isn't detailed (LoD), it will be challenging to produce an accurate detailed estimate. As we will explore later, a 5D BIM without an estimator's input and review is a recipe for disaster.
- 6D and beyond – The industry has not developed a consistent definition beyond 5D. References for 6D and beyond include procurement and operational applications, life-

cycle data, facilities management, safety and other important facility-related data points that complement BIM.

BIM: Process or Tool?

This is another subject of great debate and confusion. It raises philosophical issues and heated arguments that feed a needed dialog to raise industry awareness.

- Some feel BIM is a radical approach to defining (or, at least, critical to) a new construction project delivery process (e.g. Integrated Project Delivery or IPD, etc.). Some claim it to be yet another description of a process they've been practicing for decades.

- Others see BIM as simply a tool (or rather, a set of tools) that supports either existing or new construction project delivery processes (e.g. Lean Construction). Some identify BIM as a supporting tool of Virtual Design and Construction (VDC), an overarching concept.

- And others debate considers BIM to mean a Building Information Model (the deliverable) vs. Building Information Modeling (a process) vs. Building Information Management (a holistic, life-cycle approach and process to manage the related model data).

Since BIM means many things, depending on one's perspective, we will not attempt to delve into the debate of process vs. tool, but rather recognize it can be both, with data or information being the common goal.

However, it is important we recognize that <u>there is no single BIM tool or software product</u>. There are different BIM tools for designers, engineers, consultants, contractors, subcontractors and facility owners. In concert, <u>there is no single BIM process</u>.

For instance, consider the various dimensions of BIM (e.g. 3D, 4D, etc.). Each dimension has its own set of tools and required skill sets. In addition, there are BIM 'tools' that fit into multiple dimensions or facilitate the BIM process through collaboration, data management, and platform support.

BIM tools fit into many different categories, but can be simplified into:

- Authoring/Design Tools
- Review/Analysis Tools
- Collaboration/Management Tools

Thus, a design firm may select and implement 3D modeling software solutions, with supporting analysis and planning tools. A contractor may focus more on 4D and 5D analysis tools such as schedule simulation, and quantity extraction. And a facility owner may be more concerned with 6D and geographic information system (GIS) solutions to maintain and operate the building. It's common for construction team members to implement tools from multiple categories. For instance, a general contractor may establish its own modeling team and implement 3D conceptual and detailed modeling tools, design coordination and clash detection tools which are traditionally be part of the design process.

A professional estimator may use tools from multiple categories, depending on his or her goals, responsibilities and skills. However, we will focus our attention on the 5D process and related tools, and how these impact the professional estimator.

BIM for the Professional Estimator

There is yet another subject of confusion and misguided expectations, in that it is common to hear conversations or read articles on the demise of the estimator; how BIM will eliminate the

role of the estimator since "…BIM provides automated estimating." Whether it's the BIM software vendors making claims or uneducated participants speculating on the future, it is a cause of unnecessary upheaval in the professional estimating community. Rather than eliminating the need for a professional estimator, BIM can (may?) ultimately expand the role of the estimator in the design and planning processes. Along with that expanded role, the estimator will need new skills and tools, and may provide a higher value (with related compensation) to the organization.

BIM tools do not produce an accurate, defensible cost estimate without additional supporting data and a qualified resource (i.e. a professional cost estimator) to interpret, complement and validate the results. A cost estimator will add his or her assumptions (since the models will lack critical information), construction means and methods (again, not found in the model) and prices, non-modeled items (e.g. temporary fence, scaffolding, cranes, etc.), and indirect costs or adjustments (e.g. general conditions, overheads, fees, contingencies, escalations, etc.). Other project participants can then use the model and the supporting cost estimate to evaluate the cost effects of changes and thereby make more informed decisions about changes.

BIM tools and processes impact the professional cost estimator as follows:

- Improved visualization – BIM tools enable the estimator to better understand the project design and visualize what the end product might look like. They help the estimator determine optimal methods of construction, and simultaneously help the estimator 'build the building in his head'. BIM facilitates integrating the building with the site (e.g. Google Earth), creating building sections to better understand complex systems and geometry, and selecting objects to understand detailed properties (e.g. material specifications, dimensions, etc.). The model can also be used to aid in sales and marketing presentations or convey value engineering/analysis options. No longer is the estimator limited to the 2D representation provided in conventional 'flat' drawings.

- Quantification – BIM tools provide methods of automating some or most of the quantification effort related to cost estimating. No longer does the estimator count objects or quantities using manual methods, paper digitizers, or on-screen takeoff tools. Rather, the BIM tools can provide accurate, automated, and easily updated quantities, either through the native 3D modeling tools, 5D-capable estimating tools or through 5D analysis software solutions. Initially this process will need to be validated to build trust in the quantities and what they represent. During this time BIM quantities can be used to validate other more traditional methods.

- Quantities can be quickly and automatically updated when the model changes. Thus, one of the major benefits is the rapid iteration of estimates that support design changes, which should offer greater opportunities to study alternate building systems, value engineering/analysis options, and 'what-if' scenarios. BIM tools can also integrate with professional cost estimating solutions to facilitate the takeoff and pricing process and link BIM components to cost estimating elements.

- From the cost estimator's perspective, BIM can also be viewed as the next step in the evolution of the quantification process. Prior to BIM, the leading method was on-screen digitizing of 2D PDFs and 2D CAD drawings. Before that, it was the paper digitizers, which included flat tablets and a stylus or puck to select points on the paper drawings. Some are old enough to remember when measuring wheels and light tables were common. With each evolutionary step, the quantification process improved in speed and data management regardless of the skeptics along the way.

- Logistics and sequencing – BIM tools support the ability to integrate multiple models (e.g. architectural, structural, mechanical, electrical) to better understand the constructability of the project. BIM tools can identify where building objects intersect when they should (and should not) to aid in constructability review, trade coordination, logistics and planning. The effective use of BIM by the design team *should* result in higher-quality construction documents due to the inherit benefits of coordinated

documents. Ideally, this benefit will reduce the number of RFIs during pre-construction and after award, and many studies have proven reductions in both RFIs and Change Orders as one of the benefits of BIM.

- Documentation – The ability to document what is included in a cost estimate at a particular point in time is immense. Individual or groups of elements in a BIM can be referenced directly in a cost estimate. A 3D Model and supporting cost estimate can be presented as an integrated entity rather than two independent deliverables. Understanding what components in the model are represented in the estimate, and perhaps more importantly, which ones are not is critical when referencing the supporting cost estimate.

Model Quality: The elephant in the room

In order for the estimator to benefit from BIM, he or she must trust the model and related data. This is a fundamental shift from the traditional process where the estimator interpreted specifications and 2D documents, derived scope and quantities, "filled in the gaps", and prepared the estimate. In theory, the model contains the estimate scope and quantities, and thus the estimator doesn't need to interpret or derive them but rather extract (accept) them. In reality, the model contains some of the estimate scope and quantities. But without verification of the validity and accuracy of the model, the estimator is reluctant to accept the data and may defer to traditional means to prepare the estimate.

Thus, using a BIM estimating process, the estimator is now much more reliant on the model accuracy and completeness. Model quality is critical. Model quality will determine whether the estimator will utilize BIM in some or all of estimating process….or exclusively revert to a traditional estimating process. And anything the estimator can do to influence model quality will be a direct benefit to streamlining the BIM estimating process.

Model quality and completeness issues deserve a deeper analysis but we'll defer further exploration of this topic at this time.

BIM and the Estimating Process

Each participant in the construction project delivery process will have a different perspective on BIM. As such, if you're an estimator working for an architect, your processes, tools and deliverables may be considerably different than an estimator working for an owner, general contractor or subcontractor.

The general process, however, is fairly consistent with the traditional (non-BIM) process. A simplified workflow is listed below.

1. Modeling – Most BIM processes will start with some type of modeling (authoring or design) solution. In some cases, it may begin with a space-planning tool. Or an existing facility may be digitized via a laser scanning process to create a point cloud, which is eventually converted into a model. Whichever process precedes it, the results end up in one or more 3D models.

In some cases, a 3rd party will provide the model – the architect, a design engineer, a BIM consultant, or the owner. In other cases, the general contractor will develop or re-develop the model, either by internal modeling staff, outsourced modeling firms, or even the estimator. It's important to have BIM guidelines (sometimes referred to as a BIM Execution Plan (BIMXP, BEP, etc.)) that define the processes and deliverables to ensure the model meets the team's expectations at every stage of the process.

2. Visualization – This can range from presentations to owners/clients or in support of marketing/fundraising to simply communicating design intent to the entire project team from estimators to installers.

3. Analysis – After the models are created, they need to be inspected and reviewed for accuracy and completeness. A team may review models for lighting studies and energy analysis. Or the models may be analyzed via a rules-based diagnostic tool to ensure it meets building codes and design requirements. The estimator or modeler must understand the scope and specifications, and identify systems, errors, missing information, etc. At a minimum, the estimator must review the model to determine whether appropriate systems are included and 'fill in the gaps' as needed.

4. Sophisticated constructability review processes might include clash detection where multiple models are merged and analyzed for interferences and construction approach, sequencing and logistics.

5. Quantification – The model objects or elements can provide the scope and quantities to aid in developing the cost estimate. This can be accomplished through various levels of automation. In some cases, the 3D modeling solution will generate quantities via some internal method (e.g. schedules). The estimator or modeler will need to understand how to develop the desired schedules in order to generate the desired output (typically MS Excel). Accessing quantities from the model via another software tool is also and option. These other tools are often more estimator 'friendly' than design authoring tools. The estimator will have to know how to interpret the resulting quantities and incorporate them into the cost estimate. For example, are the total wall quantities from only a few wall segments or many wall segments? How are wall openings taken in account? The answers to these questions may impact labor productivity, material waste and pricing. Model quantities can be used as 'check quantities'. A parallel effort using existing quantification methods can be utilized to compare results.

6. Estimating – Once the scope and quantities are generated, the estimator will utilize this information in the cost estimating tool where labor, material and equipment costs, waste factors, production rates, means and methods, and indirect costs are added to complete the estimate.

7. Sequencing/Simulation (4D) – Determining when tasks occur can greatly impact pricing. Reviewing the results of connecting a model to a schedule can be very revealing. For instance, if concrete foundations or a masonry veneer wall is scheduled during winter in the north, the project will incur additional costs related to temporary heat and protection.

8. Integration - In some cases, the 5D analysis tools will integrate directly with the cost estimating solution to facilitate and streamline work processes. In other cases, cost estimating solutions will have native support for 3D model data. These tools enable the estimator to visualize and quantify the model within the native estimating tool, eliminating the need for additional visualization and quantification tools.

What to Expect

BIM is a complex concept to describe. It can be even more complex to implement and execute depending on your objectives. One should expect challenges and difficulties along the way. That is, it's usually not as easy as some might claim, and certainly not 'plug and play.' But it is achievable, and even remarkable in some cases. It is suggested to start slow in order to maximize benefits and minimize frustrations. As the entry step into BIM is mastered, advance to another step.

As a professional estimator, here's what you can expect:

- BIM tools vary greatly in terms of capabilities and complexities. Some BIM tools take months to master, while others take weeks. Some BIM work processes are very easy, while moderately complex processes can be very difficult. Very small vendors develop many BIM tools, so resource availability, software stability and support are sometimes inadequate. Many companies simply won't risk their business continuity on such a small vendor. Do your homework regarding size, longevity, and financial stability.

- Models may not be available. Some design firms simply won't release the models due to liability risks. Alternatively, design firms will release derivatives of models. For instance, as a contractor, you may not have access to the native Revit files (*.RVT), but the design firm will provide derivatives in Adobe Acrobat (*.PDF), Autodesk Design Web Format (*.DWF) format or Industry Foundation Class format (*.IFC). Depending on your goals, these alternate formats may be acceptable. Otherwise, you may need to create your own models.

- Expect multiple models. Models will be developed at various phases of the design process (Conceptual, Schematic, etc.) along with multiple iterations of each phase (e.g. Rev1, Rev2, Rev3, etc.). In addition, you may receive separate architectural, mechanical, electrical, plumbing and structural models, possibly even in different file formats. That is, the lead design firm may provide the architectural model in Autodesk Revit Architectural format, while the structural engineer may provide the structural model in a trade-specific modeling tool format. You will have to learn how to receive and manage multiple models developed using different 3D BIM design tools.

- The estimator can play a key role in collaborating with the design team and owner's rep to develop a set of BIM guidelines and execution plans that identify (among many other items) the LOD and LoD throughout the various design stages. A formal, systematic approach to defining the elements and related tasks on a BIM project is the LOD Specification (formalized by the AIA as G202-2013). In simple terms, it's all about proactive planning and communication that will foster the collaboration and automation processes of BIM. BIM projects that lack guidelines will result in unpredictable models and can make the estimator's work processes very difficult. In some cases, the estimator must establish and map model elements to estimating components, and even update the model to facilitate future estimating efforts.

- Models can be surprisingly large. Depending on project size, complexity, etc, you can expect models in the many hundreds of megabytes. The problem is compounded with multiple iterations, backup copies, etc. You can expect to invest in additional large, high-resolution monitors, workstations with multiple CPUs, Gigabytes of RAM, and Terabytes of storage along with methods to share files with other team members. BIM definitely requires a higher level of IT infrastructure than what most estimators have at their disposal. Think 'big'. Then think 'bigger'. Some of these challenges have been address by Cloud Computing greatly reducing hardware and software investments.

- Models can be inaccurate and unusable. Designers develop models for their own purposes or design intent (e.g. production of 2D construction documents or a design concept), not for cost estimating. Models or portions of models are developed at a conceptual level of detail that is inadequate for detailed estimating purposes. For instance, the modeler may insert a single 60' column instead of multiple 12' columns. This may facilitate design visualization, but it will hinder cost estimating tasks. There is also a risk of elements being created in more than one model. For example an Architect may include stairs as well as the Structural Engineer. If these models are presented in one file, the stairs will be duplicated in quantities made available to the estimator. The contractor may re-create a construction model (as opposed to a design intent model) in order for it to be usable for cost estimating or field purposes. Subcontractors and fabricators typically re-create the model to produce shop drawings and manufacture building components.

- Models are typically developed to the extent needed to print construction documents. Detail varies greatly and is often complemented by more traditional CAD detailing, most models will not include all the quantities an estimator needs to complete an estimate. Estimators must often supplement model quantities with assumptions and quantities developed by more traditional methods. For instance, the model may not include a ceiling system in a certain area. The estimator must somehow a) identify that deficiency, b) derive the quantities of the missing ceiling system using his own methods (ie: on-screen takeoff and/or correlating to related elements) and c) manually add this element to his estimate. In most cases, even if you receive a model, the traditional construction documents will also be included and serve as

THE contractual documents. A model may be provided as supplemental information. Construction documents will often have more (or sometimes different) information than the model. Complete traditional specifications are not likely to be included in the model. In a nutshell, don't throw away that 2D on-screen takeoff tool. You'll still need it for several years.

- Quantities may also be derived from linking model elements to parametric assemblies in a professional cost estimating system. Intelligent parametric assemblies can help 'fill in the blanks' based on experience and assumptions. This linking is either a function of the native estimating system, or requires an additional 5D analysis tool.

- Models are missing means and methods. Models do not include all the necessary components to develop an accurate estimate, especially means and methods of installation. For instance, a model may include the dimensions of a continuous footing, but it does not include values for shoring, additional excavation for work areas, formwork, etc.

- A model will not automatically produce an estimate. This may be one of the greatest misconceptions about BIM you will find. Models lack costs that must be derived or introduced by the professional cost estimator. Models also lack indirect or soft costs, such as contingencies, escalation, and overhead costs. Finally, models lack general conditions and general requirements. You won't find major construction equipment costs (e.g. crane rental, staging and moves) in a model. Models will provide much of the scope and quantities to support a cost estimate but not all of it. This is easily seen with phase documents preceding Construction Documents. For example an Architectural model may be the first developed followed by Structural and then finally Mechanical and Electrical.

- Change will be challenging. Most BIM tools and processes are set up for a single workflow. But the estimating process is often iterative and designs change regularly. Managing and integrating changes into a resulting estimate can be difficult. Many times it is challenging (if not impossible) to understand what's changed, what's new, what's been deleted, what's been moved, or which element properties are different between model iterations. Efficient, comparative analysis is paramount. The ability to represent variances between models is extremely valuable to the estimator as well as the entire team. Several tools have been developed specifically to address some of these issues.

- Standards, standards, standards. The BuildingSMART Alliance, in conjunction with associations like the ASPE, software vendors, and industry leaders, has been working for years on developing data exchange standards. Comprehensive standards and rules of measurement will take years to develop and be accepted by the AEC industry. Until these standards are established and implemented, exchanging model data between systems and team members, or interpreting model data in support of 5D process, may be difficult.

These are just some of the challenges involved in the 5D BIM process. But like all challenges, they can be overcome and there are plenty of smart people working through these issues.

How to Get Started

BIM continues to be one of the top 'buzzwords' in the AEC industry. BIM captures media attention. Vendors hype BIM, in many cases making it hard to determine potential from reality. Upper management often misunderstands BIM. The sales and marketing team sells it to prospects and clients. Owners demand it, but they're not sure why or what they will do with it once they get it.

The net result is pressure to 'do something' and appease reasonable or unreasonable expectations and timelines. The knee-jerk reaction is to buy some 'BIM' software so the sales and marketing team can claim 'BIM capabilities' in their pitch. This approach typically results in spending tens of thousands of dollars on software and services and little to show for it.

Instead, you can start down the BIM road with a more methodical approach:

1. Develop a plan. It needs to be achievable, measurable, and executed in small steps. Why are you pursuing BIM? Are you ready to develop your own modeling (3D) skills and staff? Do you need to provide conceptual modeling capabilities? Do you need both scheduling (4D) and estimating (5D) capabilities? Or is the goal to support the sales and marketing efforts? Are you just trying to keep up with the competition? There's no right or wrong answer. Just make sure you know why you're pursuing BIM.
2. Set expectations. The road will be bumpy. Change induces fear of the unknown, new risks, and legal issues. Expect failures along the way. Find opportunities to apply BIM when your company can absorb the additional overhead and initial productivity loss. It will take months (or years, depending on your goals) to effectively implement BIM into your organization. Think of it as a cultural change not unlike adopting a corporate focus on safety. There is no silver bullet. There is no substitute for experience.
3. Free education. Many vendors, local universities and associations (e.g. ASPE) will provide seminars, webinars, articles and videos that provide information on the various BIM processes and tools. Your design partners, consultants and subcontractors may be further along the BIM road than you are. Leverage their experience whenever you can.
4. Free software. Many vendors provide free BIM tools including modeling, visualization and analysis tools. Many vendors also provide fully functional BIM tools on a trial basis. Other vendors offer free beta software. Launch your favorite Internet browser and type in "Free BIM Software". You will find plenty of offerings.
5. **Assessment.** Is your current staff capable of utilizing BIM tools, or will you need to add new staff? Are your cost estimating processes, systems, and data ready and capable of supporting your BIM goals? Is your estimating house in order? **If not, introducing BIM will complicate and magnify your existing deficiencies.**

Final Thoughts

Regardless of the hype, BIM is more than the latest fad. It has proven its value for many years. It can streamline preconstruction operations and drive efficiencies. It can help the estimator automate many aspects of the cost estimating process. BIM can elevate the estimator role into a critical team member of the design process, and perhaps even influence the design through rapid cost analysis. But it won't happen unless the professional estimator plays his or her part.

BIM is big, and it's definitely coming (for some it's already here). It can be simple or complicated, but it's worth it.

Happy estimating.

About the Author

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