

Why Is Technology So Important to Construction Management?

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The construction industry is in the midst of a technology renaissance. BIM served as the initial catalyst for this period of innovation, but has now grown beyond “just BIM” to include innovations in many other areas such as mobility, laser scanning, and Big Data analytics among others. Supporting processes are changing as well. The construction industry is realizing that these new technologies don’t fit into previous processes.

In this chapter:

The promise of BIM
The value of BIM in construction
Where the industry is headed

The Promise of BIM

Before the advent of BIM, the construction industry generally worked in silos, where each member of a project team looked out solely for his or her own best interests and the project took a backseat (or was in the trunk) to other priorities. Further compounding the isolation issue was the prevalence of the hard bid delivery method, which contractually and financially isolated team members from one another. Both the culture and this standoffish delivery method made for a litigious environment that was plagued with waste and cost overruns. According to the book *The Commercial Real Estate Revolution: Nine Transforming Keys to Lowering Costs, Cutting Waste, and Driving Change in a Broken Industry* (Wiley, 2009), by Rex Miller, Dean Strombom, Mark Iammarino, and Bill Black, the waste created by “simple efficiency and not-so-simple bad behavior” in the United States alone in 2007 was an estimated \$500 billion. If we are to continue to function as a profession, we must ask ourselves, “Why should we ask construction consumers to pay for our mistakes?”

The promise of BIM is to build a structure *virtually* prior to physically constructing it. This allows project participants to design, analyze, sequence, and explore a project through a digital environment where it is far less expensive to make changes than in the field during construction, where changes are exponentially more costly. Today, this promise is becoming reality. An array of BIM software and mobile applications are delivering results that mitigate construction risk. Although some tools are more advanced than others, we are rarely at an impasse where some function is simply “impossible” and not able to be achieved through technology.

Where we find the majority of challenges nowadays in virtual building is that many teams fail to realize that the integration of team members creates significantly better outcomes. For example, subcontractors who are allowed to participate early in the scheduling process are able to leverage their expertise and share valuable information such as material lead times, crew sizes and installation methods that can create a more meaningful model simulation. Additionally, when a construction management team is allowed to participate in an architect’s design review meeting, they are able to see what factors are important to the client and design team and use that knowledge going forward as they prepare to build. In this book, I acknowledge these best practices and propose a new way of evaluating technology and teams holistically by using *integrated teams* that are capable of keeping pace with the rapid introduction of available technologies to deliver better construction outcomes. As George Elvin states in *Integrated Practice in Architecture: Mastering Design-Build, Fast-Track, and Building Information Modeling* (Wiley, 2007): “Integration enables a team of designers and constructors to work together toward a common goal, allowing design and construction activities to unfold in the best way for the project, rather than locking them into separate phases required in over-the-wall delivery.” It is this collaborative,

project-focused approach that allows teams to function more efficiently and use BIM to get to better answers faster. Team integration moves the focus beyond individual needs and shifts it to how information-rich models can be used to explore options and scenarios that create better projects and remove risk.

BIM has evolved. The construction community is seeing a shift from the 3D or visualization aspect of BIM to workflow-specific tools that are being directly applied to solve real-world problems, such as installation verification, sequencing, and estimating. The industry dialogue is now moving to a general questioning of how we optimize the effective capture, analysis, and dissemination of information in real time to make projects more successful.

As a result of this shift in focus, existing tools are adapting and new ones are being created to address these challenges. The adoption of BIM into mainstream construction management practice has taken the typical constructs of what it meant to be a construction manager and transformed them into a new way of looking at how we work. We are now asking new questions such as:

- What else can we do with all this information?
- Who else can benefit from this data?
- How can we use models to enable better decision making?
- What is the right level of virtual augmentation on a project site to make our teams more productive?

It's an exciting time in the AEC industry because just as applications are improving, so are many of the technologies that support its use. Technologies such as cloud computing, which gives you the ability to use remote servers to process data from any web-connected device, and the accelerated growth of mobile and wearable hardware continue to shift the paradigm of practice in construction management for designers and builders alike.

Other changes are more incremental in nature. These improvements come in the form of better software features based on user feedback as well as enhanced stability of these tools, which increases productivity and reliability.

Finally, the constant stream of new ideas and improvements in the form of innovative tools and processes entering the marketplace continues to challenge the way in which teams work and build structures at a variety of levels. In the midst of all of this change is the promise of a better way of working collaboratively with more useful information to create value in the built environment.

Since BIM's introduction, BIM software has progressed with new features and applications. Likewise, BIM has forced many in the construction industry to evolve as well and challenge the way they previously thought about designing and building projects. As a result, the construction industry began investing in new and better technology. The rapid growth of new technology for the construction market is no coincidence. Construction hasn't kept pace with other industries in regard to automation and technological improvements over the last forty years, which has created fertile ground for new tools and products that offer better ways

of working. Although innovation is encouraged, new tools require fast analysis and project testing before widespread adoption.

In the first version of *BIM and Construction Management*, I stated that BIM is not just software—rather, it is a process *and* software. Taking that one step further, we now see that successful BIM use requires **three** key factors:

- Processes
- Technologies
- Behaviors

These three components can make or break a project using BIM and technology. Think of these as the three-legged stool to the successful integration and use of BIM (Figure 1.1). Take one leg away and you are left with a pretty useless object that isn't good for much. So why are these three pieces so important?

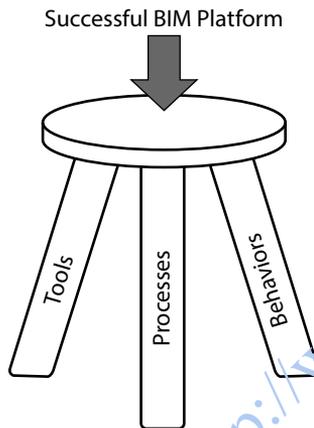


Figure 1.1 Three-legged stool of BIM.

Processes

Construction management and many other engineering-focused firms tend to take new technologies and try to make them work in old processes. This approach creates waste by not taking into account the implications of the new tool and what existing processes and workflows should change that would make an outcome more efficient. A good example was the evolution of clash detection and resolution. As clash detection started to gain traction, many teams would host a number of meetings each week that involved the entire project team to coordinate among themselves using this new 3D environment. Although the technology was better, the process used was similar to what had been done before in a 2D coordination review. As a result, many users found the new process was not only inefficient but actually detrimental to a project's efficiency. Because team members were tied up in clash detection review meetings, response times for project-related issues increased. They were also burning through valuable time and found that

their production declined steeply because of the lack of available hours. Nowadays, these meetings typically focus on two or three particular trades or scopes at a defined 2-to-3-hour timeframe to best use each team member's resources. Additionally, teams are now looking at ways of eliminating the clash detection process altogether by modeling in cloud-based tools that notify users in real-time when they create clashes.

These process shifts are critical to improvement, because they allow users to continually think of ways to improve and deliver work. In his book *The Spirit of Kaizen: Creating Lasting Excellence One Small Step at a Time* (McGraw-Hill, 2012), Robert Maurer states that "When you need to make a change, there are two basic strategies you can use: innovation and kaizen. Innovation calls for a radical, immediate rethink of the status quo. Kaizen, on the other hand, asks for . . . small, doable steps toward improvement." Successful BIM integrators realize that both large innovation and smaller process step changes are needed when using technology. Innovative change is driven by the speed at which technologies are deployed, and in order to stay relevant, you need to find ways to be nimble and look at these tools as fast as they come. Kaizen change calls for patient, iterative improvements to current tools and processes used and, at its core, require a cultural mind-set in order to work.

Keep in mind that, like a hammer or a saw, BIM is just a tool. Used with the right processes in place, BIM systems can create tremendous value for an organization. When new tools are combined with old processes, they can inhibit success as well as frustrate users. This is why it is so important to look at new tools as they become available for what they are and treat the investigation of the processes required to enable a new tool with the same rigor as that of the technology itself.

Technologies

The successful integration of BIM involves using BIM tools that work. Though this sounds simple enough, tools need to be explored further "post sales pitch." This means after the software or application salespeople have left the room, we need to ask, "Does this product improve our organization or way of working?" The strategy for how a team analyzes new technologies and selects them is important because it determines how nimble and responsive a team will be. The method for selecting tools in the construction industry typically falls into three approaches, each with different results.

The first strategy for selection and integration is the "pile on" method. In this approach, a company or organization looks at tools consistently as an *addition* to their current systems. The main hypothesis in this method is that the firm will begin by piloting the new tool and then look at how it interfaces with the company's other systems to see whether the product can meet its demands. If the tool looks like it is valuable and can be used, then the company begins a broader series of pilots that

explore it further. The intention is that the new tool will “weave” its way into the fabric of the tools used within the company and ultimately the best tools will be used, while the others will fade away.

This method is the least painful of the three strategies, mainly because it is easy and requires the least rigor and thought. However, the constant addition of new tools creates confusion as to which tools are foundational and which are being tested. The pile-on method rarely evaluates new tools against the current tools a firm is using. This type of diligence usually results in tools that overlap in functionality without a decision to remove one or another, until absolutely necessary. The pile-on method does allow for iterative or Kaizen-like changes to be made with little pain; however, a firm must be diligent about not selecting too many tools that inhibit the company’s ability to perform.

The second strategy is a “swap out,” or a direct replacement strategy. In this method, a company examines a new tool and its features and then looks internally to see which current tool or tools could be replaced. This one-to-one analysis allows for systems to be upgraded and consolidated. Direction on which tools are to be used and which aren’t are usually clearer than with the pile-on method. This method also creates the ability to continually optimize the “toolbox” of a firm to stay relevant and competitive.

One of the shortcomings of the swap-out method is that the related processes and in-depth discovery of how a team works together takes a backseat to the feature comparison of each piece of software. Additionally, this method of selection is weaker against disruptive technologies that change the fundamentals in the way a company works, because behind the tools there is usually an established way of working. The improvement cycle in this methodology often follows industry trends, though this method does allow tool selection to be consolidated and the toolbox of an organization to be focused.

The third strategy is less well known but is now growing in popularity due to the rise of lean concepts and outcome-focused thinking. Using this method, known as the “process first” strategy, a team begins by looking at their current processes and then asks “How do we want to work?” This question requires “blue sky” thinking and assumes that the technologies needed to enable this new way of working will be there when they determine their optimal working conditions. This method of selection is more tedious and time-consuming than the two previous strategies and requires a significant investment of time and research to work. The outcomes from this effort vary, but many firms come away with a plan that includes input from a broad cross-section of their stakeholders. The difference is that the team understands the desired outcomes, and the selection of one tool versus another requires considerably less effort.

In this method, the litmus test of value is whether or not the tool aligns with the firm’s vision. In some cases, no tools exist that support how a team wants to work. This situation is a risk of the process-first strategy; however, it is also fertile ground

for customized solution development that meets the needs of the team. These custom solutions can be developed internally or with a third-party developer, or information can be provided to software vendors to develop and integrate into future releases of existing tools. This method of technology selection provides a framework for identifying tools that help a team reach its desired end state, because it allows the most flexibility in a rapidly changing environment and limits the “analysis paralysis” stage that many organizations face when analyzing tools from too many perspectives.

Unless a firm truly hasn’t changed tools in some time, it will typically use one of these three methods or some combination. Whether the methodology of selection was purposeful or less rigid, a firm that wants to continue to adapt and improve should look at the way it analyzes and selects tools. Doing so determines the speed and efficacy of that company to stay at the forefront of technology and market trends.

Overall, BIM in construction is seeing a trend of consolidation in quantity and a focus on cross-platform integration. Some vendors are rising to the call of interoperability, application programming interfaces (APIs), and open source information sharing that limits redundancy and starts to create interesting new ways of using BIM information. This continued improvement in BIM software can largely be attributed to user communities and feedback. Whether that feedback comes from online forums, consumer councils, or involvement in industry organizations and committees, the lifeblood of improvement in BIM relies on users in our industry to take an engaged stance in the future iterations of existing tools in these venues. Just as important is the willingness to be “sold to” by new companies with new ideas to support a dialogue and cultivate a culture of innovation and advancement within the construction community.

Behaviors

Of the three key components to successfully integrating BIM, behaviors are the most difficult to change. As Scott Simpson of design firm Kling Stubbins says, “BIM is 10 percent technology and 90 percent sociology.” The core of BIM is far more than updating software—it is a cultural shift in the mind-set in the way construction management teams collaborate. So, what do we mean when we say “behaviors”? When we consider what makes BIM work within a construction project, the core component becomes *enabling behaviors*. Think about it. Would you rather work with a team that is excited to work in a cutting-edge environment—or a team that is overly skeptical and limits further progress by being closed-minded?

Not a tough decision to make.

Teams need to fully realize that a future forward mind-set is just as important as the technologies and processes behind it. Those who misunderstand this principle will quickly find themselves irrelevant in the design and construction market. As the philosopher Eric Hoffer says, “In times of change, learners inherit the Earth, while the learned find themselves beautifully equipped to deal with a world that no longer exists.”

Although we have discussed the importance of personal behaviors, it is also important to note that organizational behaviors can impact the successful integration of technology as well. A company that has a culture of innovation and a nimble attitude to begin with will create a persisting dynamic where change is a constant and improvement and analysis are to be expected. Conversely, an environment that is resistant to change and that stifles innovation will become exponentially more difficult to create that enabling dynamic that supports the successful analysis selection and use of the right tools that may translate to process changes.

Behaviors Matter

Construction management firms are facing an increasingly competitive environment all over the world. This is particularly true for large projects, where significant effort is required and large amounts of revenue can be made or lost. In many of these projects, joint ventures (JVs) are used to take the best of what both teams have to offer as well as spread out the risk, bonding, and insurance requirements. It is important to note that when JVs are being created, individual teams are selected based on various factors, including their experience, portfolio, client relationship, technological capability, availability, and behaviors. Why behaviors? Well, these projects often carry a significant amount of risk, not only as it pertains to the construction project but also as two or more companies with different cultures begin working together. For this reason, teams with the right enabling behaviors often find themselves as a desired partner, whereas teams resistant to change often find themselves left on the sidelines.

One of the main themes in Finith Jernigan's *Big BIM, little bim* (4Site Press, 2008) is the concept that truly successful BIM is much more than just BIM software (little bim); rather, it is the assemblage of the tools, processes, and behaviors (BIG BIM) required to make BIM truly effective. Just as BIM tools are becoming more collaborative, so must our behaviors and mind-sets. We as an industry have a significant opportunity to capitalize on what has the potential to revolutionize the way construction is delivered going forward by shifting our attitudes and mind-sets to more enabling behaviors.

The Value of BIM in Construction

The value of BIM in construction comes in many shapes and sizes. Whether it's the ability to save time through automated functions, eliminate the need to travel to a meeting, or save money because better information is available earlier to make cost-effective decisions, they all have the same focus: results.

It's hard to imagine an area of our daily lives in which technology doesn't affect us, particularly in the workplace. The same is true within the construction industry. The advent of BIM and the rise of application-based technologies have opened doors

and arguably created one of the most exciting new dynamics since Microsoft Excel. Over the last 50 years, the construction industry has had just a handful of notable technological innovations compared to other industries. Granted, there were many innovations in material research, installation methodologies, and energy efficiency, such as prefabrication, eco-friendly materials, and green building design. However, the technologies used by project teams for construction management remained largely the same. Now, innovation is becoming a part of the way contractors deliver their work and differentiate themselves from their competitors. As a result, we are starting to see a healthy ecosystem of supply and demand for ever better tools between technology vendors and construction management firms willing to invest to drive efficiencies, as is evident in the rise of contractors adopting BIM technologies (Figure 1.2).

Contractors' Current and Future Expected BIM Implementation Levels

Source: McGraw-Hill Construction 2013

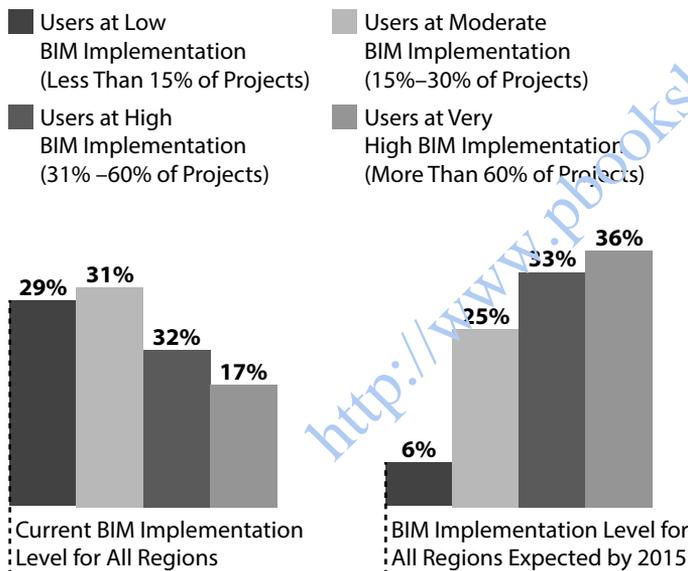


Figure 1.2 Expected growth trends of BIM

BIM in construction management has a unique history. It is important to understand this unique evolution in order to best understand its value and trajectory (Figure 1.3).

BIM as we have come to know it is largely based on object-based parametric modeling technologies that were developed by the Parametric Technologies Corporation in the 1980s (source: *BIM Handbook*, p. 29). BIM for the construction industry was commercially available as a tool in the early 1990s with the ability for computers to handle the size and processing requirements of 3D CAD models. The

acquisition of Navisworks (Formerly: JetStream) by Autodesk in 2007 served as a catalyst for BIM adoption among contractors because of its ability to integrate multiple BIM filetypes. As BIM became more mainstream from 2007–2010, the series of follow-on applications, services, and hardware that were associated with this exciting new tool grew significantly. This surge in quantity of BIM-related plugins, add-ons, and applications created the two new dynamics that we outlined previously. The first dynamic was the early stages of the technology “renaissance” that moved the topic spotlight to the construction space and where it stood in its use of technology. The second dynamic created was the challenge imposed upon construction firms to select the right BIM tools that worked together to create value. This phase of BIM history was largely viewed as the beginning stages of BIM, and it quickly brought about a call to action between these tools on the topic of interoperability and the free exchange of data between systems, which continues to be a discussion point today.

The percentage of companies using BIM jumped from 28% in 2007, to 49% in 2009, and to 71% in 2012. For the first time ever, more contractors are using BIM than architects.

Source: *The Business Value of BIM in North America: Multi-Year Trend Analysis and User Ratings SmartMarket Report*, McGraw-Hill Construction, 2012.

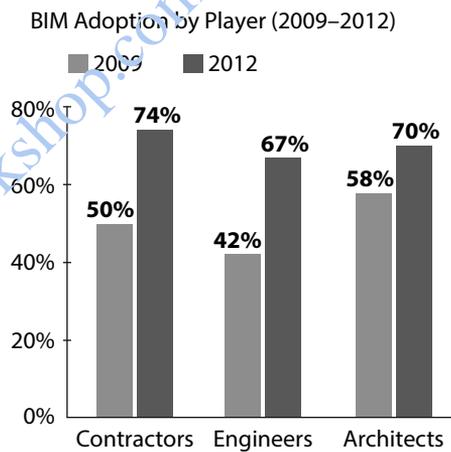


Figure 1.3 Growth of BIM adoption since 2007

Some early adopters began integrating BIM technologies within their firms with the intention of differentiating themselves from their peers. Many companies tried to label their unique brand of BIM as something special that they alone understood and that no one else had. Whether it was key staff, project experience, or custom-developed tools, the need to stand out from the growing BIM crowd became increasingly important. The adoption of the tools often took the “pile on” approach as described earlier in this chapter, and it seemed that competition was driven solely on the basis of who had the latest new tool. This drove many early adopters to question the context and value of BIM tools and workflows in order to make them more competitive. Ultimately, this served as a catalyst for broader thought and deeper questioning.

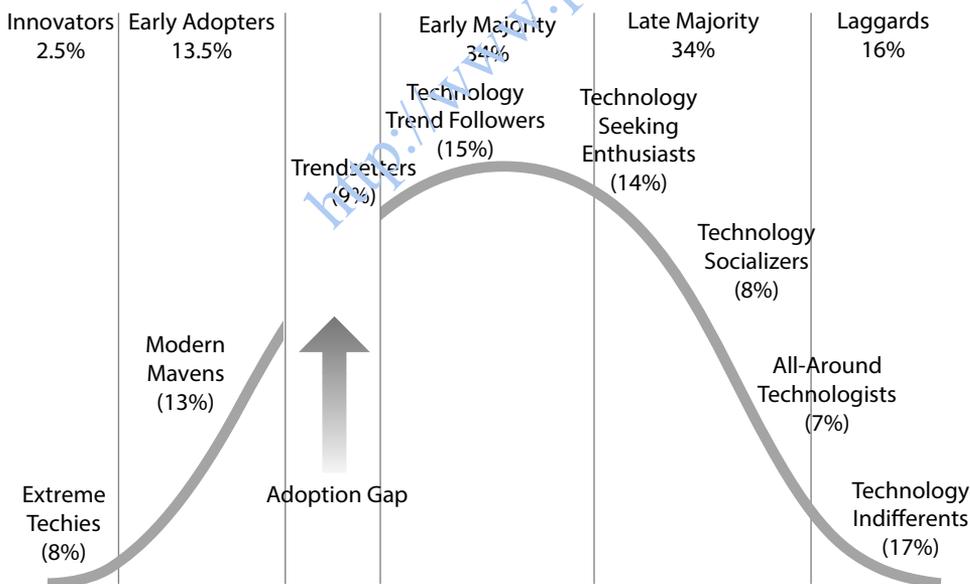
Another aspect contributing to the rise in quantity of innovators and early adopters can be attributed to BIM being requested by forward-thinking construction

consumers such as the General Services Administration (GSA), United States Army Corps of Engineers (USACE), Disney, Google, Coca-Cola, and other large-construction consumers. In order for construction firms to stay relevant to these customers, the need for a compelling technology approach rooted in proven deliverables and consistent results became more important.

Many technologists predicted that it would be decades before BIM took hold as a tool and process. Although initial efforts were slow and followed the trend line of a traditional technology integration cycle (Figure 1.4), BIM has since taken the AEC industry by storm and firms that are now using BIM have surged from 28 percent use in 2007 to 74 percent in 2012 (source: *BIM SmartMarket Report*, “Business Value of BIM in North America”) and has quickly shifted from early adoption stages to the middle and late stages. As the dust settled from the initial excitement and optimism, early adopters were replaced in number by the early majority, who investigated these new tools at a much deeper level than surface promises. Ultimately, these industry experts and analysts began to weigh in on which tools provided clear value and delivered on their promises and which ones did not. Many communities and organizations were created as a means to capture this information.

Segments and the Technology Curve

Conventional Distribution for Technology Adopters



Source: *The Nielsen Company and Cable & Telecommunications Association for Marketing (CTAM)*

Figure 1.4 Traditional technology adoption cycle

From 2007 to 2012, the factors influencing the use of BIM shifted. In 2007, the second-largest factor in increasing use of BIM was owners demanding it on their projects (Figure 1.5). However, in 2012 owners' demand for BIM fell to the number four slot as interoperability, functionality, and clearly defined BIM deliverables took its place (Figure 1.6). Although owner requirements are still a major consideration in BIM use, we now appear to be at the crest of BIM adoption in the construction industry. Proof of deeper questioning and analytical thinking that is consistent with trends of the more careful early and late majority adoption cycle group continues to surface as more professionals from all over the world explore the depths and potential for BIM in construction.

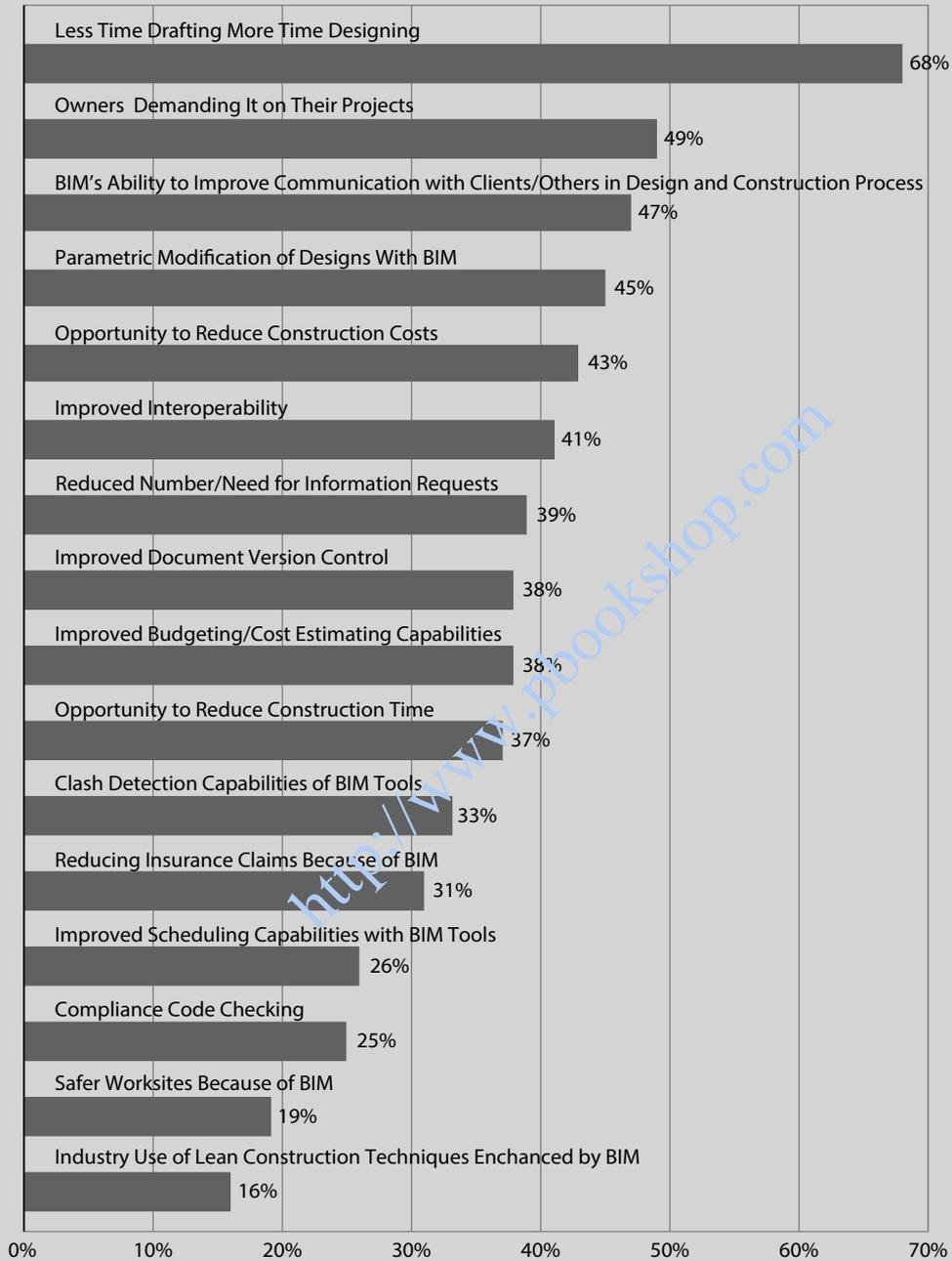
As with the traditional technology adoption cycle, the innovators, early adopters, and trendsetters pass the baton to the early and late majority, which is largely where BIM is in its technology adoption life cycle currently. The early and late majority users, characteristically, are more analytical than “techie” and have had a significant impact on BIM use, with more to say about workflows and the quality and organization of data than their predecessors. There continues to be a big focus on interoperability between tools and a more in-depth look at the value case of large amounts of data that host or link to parametric (model) elements. However, the industry is still defining the value of BIM information as a whole. This presents many opportunities for future innovations that will go through additional technology cycles. Many industry organizations host presentations and discussions that have moved beyond introducing BIM as a concept to more detailed analysis on planning, organizational structure, and process change dialogue.

This is a very exciting time for BIM and technology within construction. We are now seeing new tools and processes come to market that are focused on value that align to processes and consolidate functions. Examples are the new version of Vico Office, which integrates time and cost functions; Autodesk 360 Glue, which eliminates the need for working on files in a LAN or WAN configuration; and Bentley's ProjectWise Construction Work Package Server, which integrates the model, schedule, and task planning.

So where is the value in BIM now?

Simply put, the value in BIM is still in the *information*. However, the value is more known than before and it is now this better connected, simpler more results focused approach that is guiding the use of this information. When we think about the potential uses for a virtual model that is able to contain information about each individual door, roof top unit, slab, and window, we begin to understand that the implications for estimating, scheduling, trade coordination, and installation are still profound. The design and construction industry will continue to become more efficient at creating and using models. As a result, teams are exploring ways of using the data and information produced from models to eliminate waste in redundant data entry and points of input as well as to spot trends, patterns, and issues that we simply were not capable of capturing before the introduction of BIM.

Factors Influencing the Use of BIM



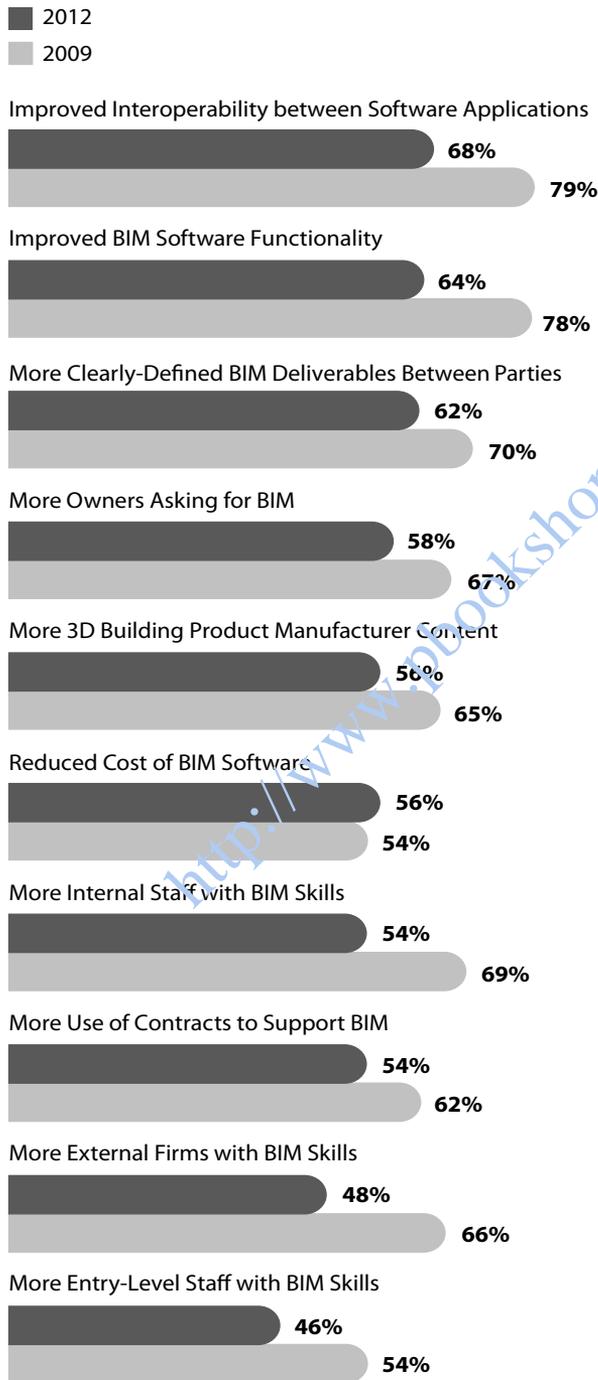
Source: McGraw-Hill Construction Research and Analytics, 2007

Figure 1.5 Factors influencing the use of BIM: 2007

Most Important Factors for Increasing BIM Benefits (2009 and 2012)

Source: McGraw-Hill Construction, 2012

Figure 1.6 Most important factors for increasing BIM benefits: 2012



It's Not Just 3D

It is important to understand that though most have come to understand BIM as a 3D tool, it is also an information-rich database that links to and controls those model components; this is often referred to as “parametric modeling.” There is significant value in the three-dimensional aspect of BIM, but its ultimate value lies in the ability to aggregate, edit, sort, and compile this information to drive at better answers to design and construction questions such as “What is the best sequence to install this piece of equipment?”, “How much square feet of raised flooring do we have in this facility?”, and “What are the parts I need to build this manufacturing plant addition?” If a 3D element is in the model, chances are a whole host of information is behind it that can be used in a variety of ways.

Where Does BIM Play a Role in Construction Management?

BIM continues to redefine the way the construction sector builds and works together. The core value of BIM that the construction industry should be aware of is the ability to take model information and extend its use by giving it meaning for other related workflows and processes. These workflows include impacts to basic functionality such as estimating, scheduling, logistics, and safety. These new capabilities have opened doors for faster population of data into these systems to deliver work earlier, safer, and with better quality.

Whereas data input is becoming more efficient, there is also an industrywide push for constant interconnectivity of data within these systems to behave more like an ecosystem of information in lieu of one-off file exports or imports. In other words, as Daniel J. Boorstin says in his book, *The Republic of Technology: Reflections on Our Future Community* (Harper & Row, 1978): “Technology is . . . fun, but we can drown in our technology. The fog of [too much] information can drive out knowledge.” In essence, too much information can create risk by diluting the focus of a project. Information is critical in project management; however, when it becomes too cumbersome to manage or decreases effectiveness through overanalysis, it can be detrimental.

Lastly, we are seeing a big shift in collaboration methodologies and an increase in the frequency of information sharing. New tools such as box.com, Dropbox, Egnyte, Newforma, and other web-based file-sharing platforms are making the process of information sharing easier. Additionally, the cloud has significant potential to impact the way construction is delivered and managed, from rigid and limited to flexible and scalable. In the construction market, BIM and other related technologies have a significant place at the table for almost every phase of construction, and adoption continues to increase at a rapid pace (Figure 1.7).

Levels of BIM Adoption in North America

Source: McGraw-Hill Construction, 2012

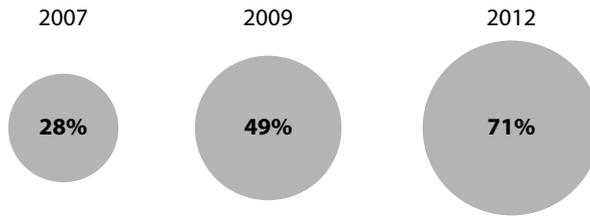


Figure 1.7 Increase in BIM adoption 2007–2012

Team Engagement

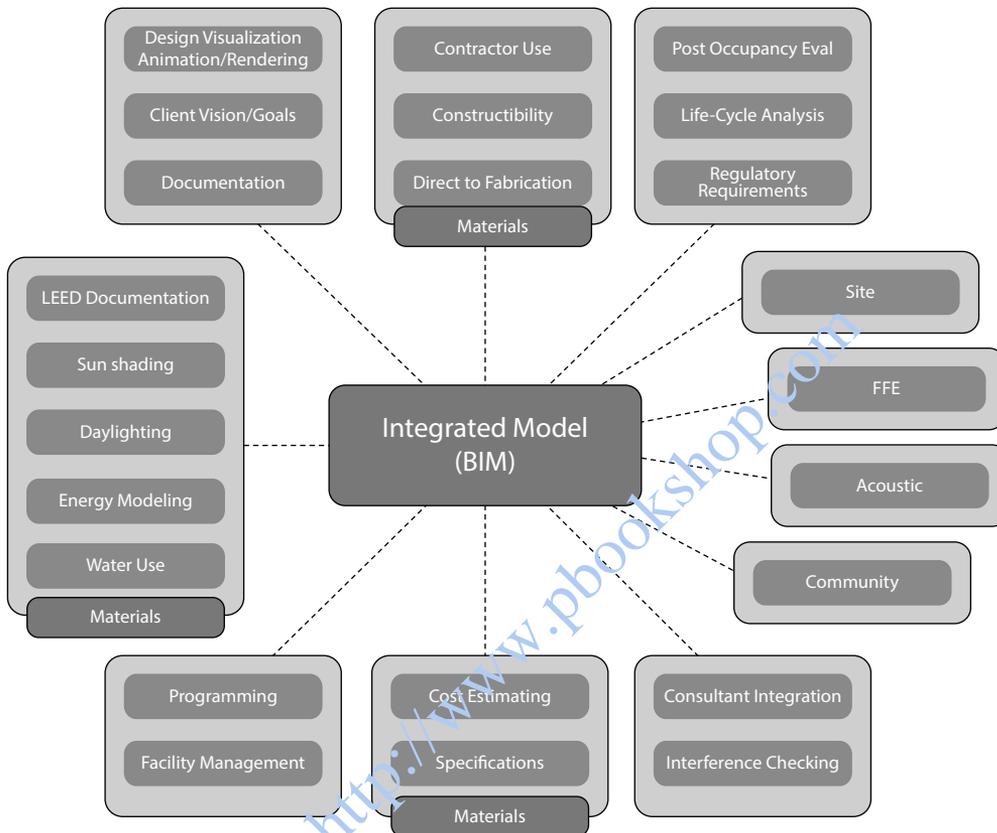
When it comes to communication and planning, the use of technology is critical in passing and sharing information. The use of BIM on construction projects is a great enabler for better team engagement. To ensure the successful participation of a team, BIM-enabled projects require that project plans be created to establish expectations and iron out project details upfront. The biggest inhibitors to engagement are confusion, complexity, and lack of communication. For this reason, it is paramount for each team member to understand the details of a project.

To best understand the use of BIM, team leaders need to create plans that describe the tools that will be used, acceptable file formats, and when team members can expect to receive information, among other factors (Figure 1.8). These plans will be covered in Chapter 2, “Project Planning,” but note that the trick to solid team engagement is making it last throughout the project. It’s easy for the excitement of a new project and a new set of challenges to make a team come together. However, successful team leaders know that keeping everyone engaged as active participants is key to project success.

Project Pursuit and Business Development

Owners continue to become increasingly informed about BIM and technology in construction, and many owners want to take more active roles in understanding what the teams proposing on their projects are capable of and where they have experience or have driven innovation. Particularly of interest to owners is the ability to leverage models throughout the design and construction process to remove unknowns and mitigate as much risk as possible in their projects. This can be accomplished in a number of ways, such as enhanced visualization (Figure 1.9) to understand material choices more accurately, estimating to eliminate cost overruns, more detailed sequence and scheduling analysis to reduce negative schedule impacts, and creating safer job sites by laying out more easily readable 3D site plans. Lastly, many owners are beginning

to use as-constructed models for life-cycle efforts to better inform operations and maintenance processes and carry information about the final project into asset and facility management.



Source: Image courtesy of Eddy Krygiel

Figure 1.8 BIM has multiple stakeholders, so defining team members’ responsibilities is critical.

In the initial project pursuit phase, it is important for construction management teams to articulate their tools and processes as well as their desired outcomes and where applying a certain technology will either remove risk, create value, enhance building performance, or better enable collaboration and communication. This can be accomplished by articulating the expectations and intentions of the team in BIM execution plans and information exchange plans before the start of the project.

Teams should demonstrate where they have analyzed an owner’s needs and selected a tool that has created value. In applying BIM and technology in

construction management, it is important to remember that not *all* tools are meant for *every* project. For example, the suite of tools selected to build a new high school will be different from those BIM tools selected to build a new cancer research center. The information required to build each is just as different as the facilities themselves. Though some of the information will be consistent between each project, it is important for a team to develop a methodology of selecting the right tools.



Figure 1.9 Project visualization example

As teams develop expertise in applying BIM in a variety of projects, the tools and processes become clearer and teams recognize opportunities to innovate as a result of enabling behaviors and cultures. For instance, a team that has become proficient at model-based scheduling may find a project owner who requires the integration of cost into the project. Using their foundational understanding of

model-based scheduling, teams may be able to integrate costs into that schedule as well. Innovation in the BIM process is critical to advancing both the industry and individual firm performance.

Planning for BIM Success

A myth in BIM is that a team should start immediately using BIM during the preconstruction phase. Jumping into BIM without having an execution plan or information exchange plan severely limits a team's ability to perform. During construction is not the time to work out how, if, and when systems should share and link to data throughout your project. In our experience, the success of BIM is determined by how well BIM use is planned for and communicated among a project team well before any preconstruction or construction activities begin.

The analytical nature of the tool and the powerful information that is tied to building information models creates a tremendous opportunity to capitalize on the use of BIM throughout the building process. These uses include estimating, quantity validation, sequencing simulation, design updates, version-based model analysis and owner/user group visualization, prefabrication detailing, material impacts, life-cycle energy usage, and life-cycle cost estimates that include utilities and operations, and so on. However, it is critical for a team to determine up front which uses and responsibilities make for a smooth project.

Using Contracts in Planning

Just as BIM and technology should be planned for, a best practice in using BIM is to contractually establish expectations, files to be used, frequency of distribution, and quality control checks. An array of BIM contract addenda is available from the American Institute of Architects, Design-Build Institute of America (DBIA), and Associated General Contractors of America, and more are detailed later in this book.

Standard BIM planning tools are available in the industry as well. These standard plans include the Penn State BIM Project Execution Planning Guide, the DBIA BIM Manual of Practice and Checklist, the USACE BIM Project Execution Plan, and the GSA BIM Guide, which are all available at no cost. Additional resources are available for purchase. These plans and guides are meant to act as a template for teams to detail how they will work to deliver a BIM project. In the case of the USACE and the GSA, their plans are an owner-driven standard project requirement that each team must complete and get approved. This creates consistency in deliverables and language while ensuring that the basic owner's requirements are met.

Some project teams decide to forgo these boilerplate templates and develop their own BIM execution plan or information exchange plan and include them as attachments to subcontractor agreements. Additionally, some customize their own plans to more specifically address the needs of their project, team, and contract formation and the desired end state. These customized plans are typically built around a number of best practices and years of experience. I recommend that early BIM adopters begin with the boilerplate documents to familiarize themselves with their parameters and refine these documents before creating one from the ground up.

Another tool that is growing in popularity is the memorandum of understanding (MOU), which is typically found in project types like Design-Build, IPD, and other forms of integrated delivery. The MOU is a charter document that maps out the intentions of the project team, the high-level deliverables of a project, resolution methods, and goals. A project team signs this agreement and uses it as a tool—and quite often as a contract addendum that needs to be adhered to. MOUs are typically used if little project information is available at the time the project is being pursued.

Regardless of the plan used, you must consider a number of pros and cons when structuring a team. BIM aligns to the construction industry at large that is headed to a collaborative and more integrated team approach, where the project is the focus and team members determine their value and use tools that enable them to make better decisions together.

Scheduling

Schedules in construction are meant to clearly define how projects will be assembled with defined activities and sequencing logic that establishes durations and directs the overall flow of progress on site. Schedules have traditionally been created in a vacuum by one or more dedicated scheduling professionals, whose role on a project is to take an educated guess based on past performance and other available industry data to generate a project timeline. Although this method of scheduling has long been considered the golden standard, it is by no means effective. According to *The Commercial Real Estate Revolution: Nine Transforming Keys to Lowering Costs, Cutting Waste, and Driving Change in a Broken Industry* (Wiley, 2009), by Rex Miller, Dean Strombom, Mark Iammarino, and Bill Black,, traditional project management schedules are wrong 70 percent of the time. So why do we keep using them?

One answer is that there simply is not another available solution. Yet, many contractors are now realizing the value of the integration of the model with schedule information. From this effort, firms are producing collaborative simulations with subcontractors to validate and ensure schedule accuracy as well as create efficiencies. The integration of schedules into BIM has been coined “4D” as well as

“model simulation” studies and “sequencing animations.” Model information for scheduling can be used a number of ways. Because virtual elements or geometric components are visible in a model environment such as Navisworks and Synchro, they can be animated. By linking these assemblies to schedule data, a video of the project’s construction can be simulated. Additionally, these linked simulations can also detect incorrect schedule logic through sequenced clash detection. These simulations visually highlight issues such as equipment being set on raised pads prior to curing being completed, or beams appearing in thin air without supporting columns or superstructure.

BIM in scheduling continues to create a higher level of project clarity and has proven to be an effective means of communicating with a team visually for how a project is going to be put together. The tools are growing in sophistication, and many are starting to provide features such as the ability to slice models into phases and schedule tasks as they would be constructed for Location Based System (LBS) or Advanced Work Packaging System (AWPS) work, as well as introducing optimization features such as line-of-balance schedule views (Figure 1.10).

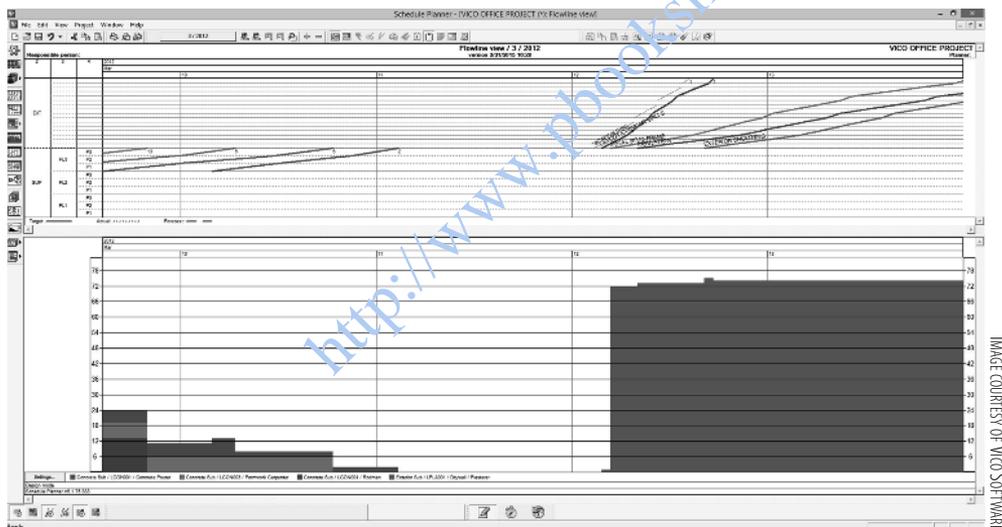


Figure 1.10 Line of balance, Gantt, and resource-loaded schedule view

BIM and scheduling have taken on a more in-depth relationship as many tools now directly link to each other. These tools, including Navisworks, Synchro, and Vico, make the process of updating and editing both the model files and the schedules much easier. Additionally, schedules can be loaded with cost and crew information, which can be validated before work starts to ensure the correct amount of materials and

crew size. Later, in Chapter 5, “BIM and Construction,” will go through the process of integrating schedules into BIM files and what tools are available in the market. As tools become more collaborative and the industry continues to shift toward more lean scheduling methods, traditional scheduling methods will be seen less and less.

Logistics

Traditionally, site plans have been used as the vehicle to coordinate site movement, safety, laydown, storage, equipment use, and access efficiency. BIM combined with geographic information systems (GIS) technology has changed the way we create site plans by adding a level of detail, particularly in more vertical construction. The integration of intelligent equipment and objects that communicate with humans will make our jobsites safer and more productive. Beyond site logistics, the integration of wearable technology—such as Google Glass, Apple Watch, and the Oculus Rift virtual reality goggles—with BIM and virtually hosted information is becoming a rising trend, with massive potential for spatial validation, onsite access to information, safety, and augmented reality (Figure 1.11).



PHOTOGRAPH BY MARCIO JOSÉ SANCHEZ/AP

Figure 1.11 Apple Watch

Site safety risks are an area in which technology will continue to take a role in mitigating. BIM and technology will continue to be looked on as a resource for the mitigation of risk and better visualization of onsite conditions. Actual site conditions

layered with BIM data and real time equipment locations could make for safer jobsites around the world. Lastly, the acquisition of information earlier in a project life cycle allows team members to make issues known and addressable at an earlier stage in a project and to design in safety to the way a project is constructed.

Estimating Cost

BIM-derived estimating (also known as 5D) has been long believed to be the “golden goose” of BIM in the preconstruction phase of a project. Conceptually, BIM-derived estimating uses the database behind a building information model to either directly link those model components to unit cost or to cost assembly recipes to produce an estimate. For example, a model that contains 10,000 sq. ft. of drywall would link to a unique cost recipe including such information as the crew size, hourly rates, material costs, and productivity rates. This enables the model to define how long it will take to install the amount of materials being pulled from the model. In essence, the schedule becomes a product of how much “stuff” you are going to build in a particular order (Figure 1.12). This is unique compared to previous methods, where the schedule and the estimate often operated as two autonomous files and rarely were tied together. Products such as Trimble’s Vico software allow for the building information model to become more integrated as it removes the process of linking disparate schedules to the model and in effect contains both the building components (3D), schedule (4D), and cost (5D) information within one tool.

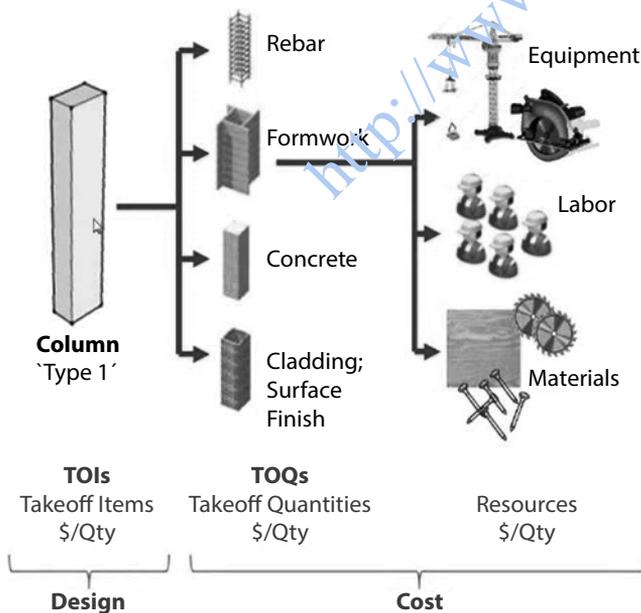


IMAGE COURTESY OF VICO SOFTWARE

Figure 1.12 5D data flow

BIM estimating has grown significantly in sophistication and ease of use since early iterations of the software. Now tools have begun to make the process of BIM estimating more seamless, allowing for the integration of “non-model”-related data such as 2D PDFs and CAD drawings to be used in the takeoff process. Additionally, aspects of scope, such as general condition costs and equipment leasing, are now able to be integrated into an estimate, whereas before this they would have to be done in two separate environments. The industry now has a more robust understanding of how to accomplish model-based estimating, and many best practices are available from vendors, user groups, and industry associations to help tackle estimating modeled versus placeholder or assumptions. Model-based estimating still requires a significant investment to set up the cost databases and processes used to estimate and update BIM-derived information. However, many firms are seeing efficiencies in updating and accuracy.

Other innovations such as cloud-based model collaboration is starting to have a unique impact on a team’s ability to complete estimates. Tools such as Onuma System (Figure 1.13) allow multiple users to collaborate in real time in the cloud with the same datasets. Collaboration in construction has started to shift beyond the model. It is web-based and real time, and it involves input from several team members and aims to speed up work. Enabled by technology, the process of collaborative estimating and scheduling is beginning to take hold.

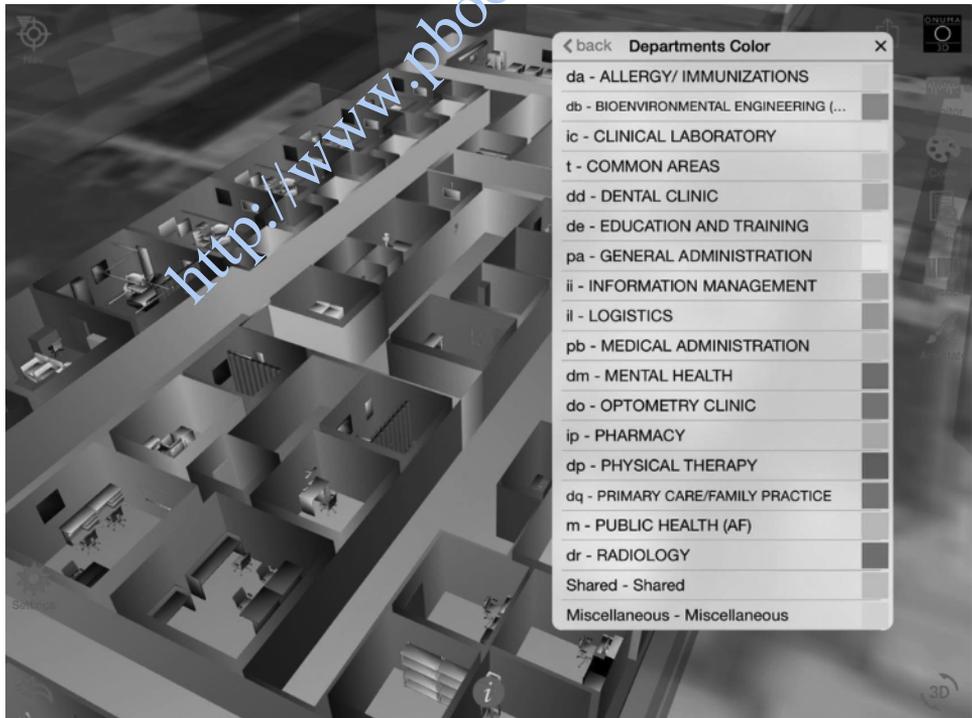


Figure 1.13 The Onuma System on the iPad

Constructability

Constructability is a project management technique that reviews construction logic from beginning to end during the preconstruction phase to identify roadblocks, constraints, and potential issues. The use of BIM during constructability for spatial coordination was a catalyst for the rapid adoption of BIM in the construction industry. In an interesting progression, the value of using models to coordinate system and structure layout has been transformational in how the construction industry now handles conflict resolution between systems. Previously, spatial coordination issues were addressed over light tables by individual reviewers. Now, models are reviewed in 3D, collaborative environments to best understand the issues and then resolve them (Figure 1.14). Often the resolution of conflicts can be achieved in the same environment, significantly reducing the amount of phone calls, e-mails, and other coordination efforts. This area has garnered perhaps the most sophistication in the construction management space as many contractors now use BIM as a best practice in coordination of their projects, regardless of project value, type, or size.



IMAGE COURTESY OF BLACK & VEATCH

Figure 1.14 Model coordination review meeting

The process refinement of constructability, also known as conflict detection and resolution, has grown in scope and sophistication as well. It is not uncommon to see clash detection reviews now include installation and maintenance clearance objects, or “blobs,” in front of equipment. These blobs allow team members to understand that even though there is nothing physically in the space, the space is actually needed

for accessibility and maintenance purposes (Figure 1.15). For example, a mechanical subcontractor may place a 12" clearance blob in front of a piece of equipment to ensure that the filters in a VAV box can be replaced. Overall, constructability and systems coordination in BIM is a known and accepted process in preconstruction coordination, with many firms using BIM as a best practice.

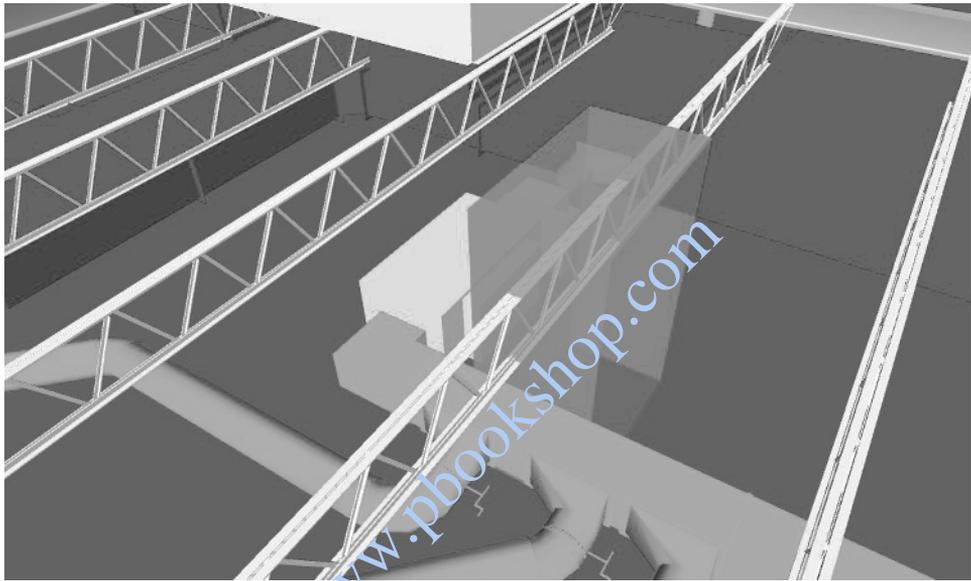


Figure 1.15 Clearance object in front of equipment

When you think about it, clash detection ultimately represents a *failure* in the design process. In the past, BIM teams were limited by technology. One of the main limitations was model coordination lag due to the inability to transfer large model files over the Internet. Although model file sizes vary, many projects can range from a couple of megabytes (MB) to some as large as several gigabytes (GB). For this reason, the ability to work on local files over the tried-and-true local area network (LAN) ceased to become an effective solution if the team was working in different places. Unfortunately, the workflow became a “snapshot” approach to the BIM process. Because information could not be shared with team members fast enough, design teams worked on an instance of the main or central model in a vacuum on their local devices or networks and would then reconcile their updated model with a central or composite model at a later time only to learn that there were now a whole new number of issues to resolve.

There was a major roadblock to this process. As multiple team members all worked in their own instances of a model, conflict resolution became a time-consuming process and multiple “speed bumps” in the road caused pause for coordination once models came back together. Many teams found resourceful solutions. One such solution was co-location; with this approach, the entire project team would physically sit in the same room. Another solution was staggered design development phases, which would let a specific discipline “own” the model, add information, refine their design, and then pass it to the next user. These methods were effective to some extent, but for many projects they were unsustainable in the long term. Co-location, for instance, typically had costly travel expenses. As for staggered phases, project timelines often didn’t allow the luxury of waiting for design development to be passed from one set of users to another.

As a result, software vendors and application providers have begun to consider other solutions. One is to co-locate virtually by creating an environment where the project team, regardless of discipline, can “plug and play” via the cloud. This solution is promising and allows model file transfers and real-time coordination, and enables geographically disparate teams to work together. Over the last five years, there has been a narrowed focus in collaboration in the cloud. To some, cloud computing means a remote hosting offering; for others, it involves using a network of remote servers to accomplish such tasks as data crunching or *Big Data compilation* (where large amounts of data are sorted, filtered, and analyzed to identify patterns and trends). As it pertains to BIM, the use of cloud-based model collaboration through a virtual desktop environment (VDE) has opened the doors wide for an exciting new collaborative platform as well as a tool to complete analysis and design faster.

This new network structure creates a platform of interaction that often extends well beyond the project team into other areas, such as the ability to use crowdsourcing and get third-party insight into construction issues. Because of this new platform, we are starting to see real-time clash detection occur as models are being developed. This new ability frees up time from the traditional constructability review and resolution process and puts users on a course for better effectiveness and time management. Tools such as Autodesk BIM 360 Glue (Figure 1.16) introduce a real-time clash alert that lets users know when the systems being modeled are creating conflicts with other systems.

Analyzing Data in BIM

The ability to analyze the large amount of data available in BIM or that is gathered through the design and construction process creates a broad array of possibilities. Many systems have now been developed with a particular focus on aggregating this data and making it more meaningful during design and construction. Some of these

tools focus on work such as equipment management, safety, inventory tracking, issue management, document accessibility reports, and an array of other solutions that aim to simplify, automate, and streamline work that happens in the field.

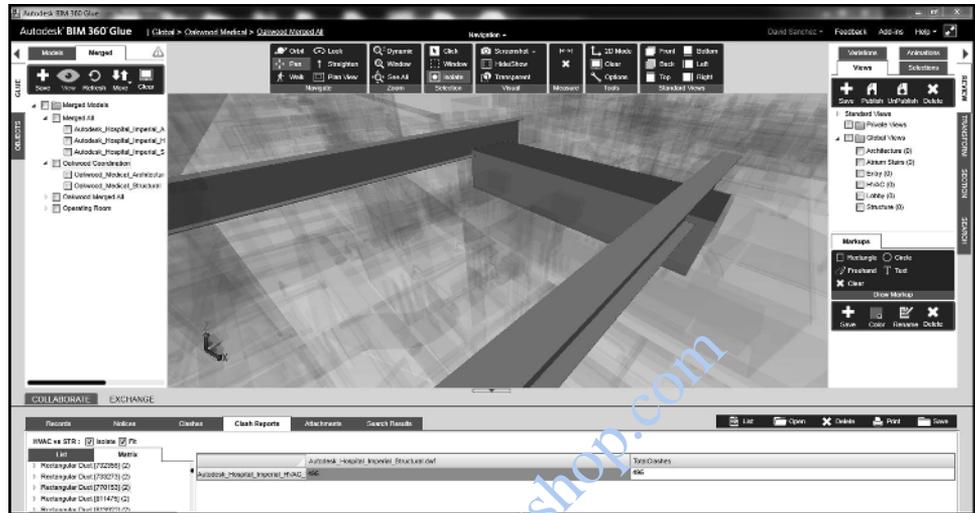


Figure 1.16 Autodesk BIM 360 Glue

The topic of analysis is almost too broad, and for this reason, we will focus on tools that are used during construction that achieve meaningful metrics that can assist a construction management team in becoming more productive, safer, and more connected. The field of analytics is relatively new in construction. Tools such as Sefaira (a carbon footprint calculator), STAAD (used for structural analysis), Trane TRACE (a computational fluid dynamics tool), and many other data-intensive applications have largely focused on the design space. The value proposition in design is much clearer in part due to the availability of model data that can connect to current software in-house for analysis functions with a clear end product—that is, structural analysis, energy use, carbon footprint, daylighting, and so forth.

In construction, we are just now beginning to see the integration of analytic tools into the way we work and coordinate and in the way we build. There is an exciting value proposition in some of the data and what it will tell. Particularly of interest will be the constructs Big Data will challenge and how teams validate reaching their goals through measured outcomes and navigate quickly through volumes of information.

Construction projects continue to become more complex. The requirements asked of construction managers are growing in the areas of safety, reporting, and information management. Adding to this complexity is the rise in quantity of available information from relatively new technologies such as BIM. Although this

presents unique opportunities, it also creates new challenges to managing data. The management of this data is directly related to a certain amount of risk. Managing information like safety reports, material inventory, subcontractor performance, schedule updates, accounting, and quality control have traditionally been in the scope of construction management firms. Now as the construction industry has largely accepted the value of BIM, it is now faced with other issues. Who is responsible for managing the information in the model? What other value can be extracted from its use? The future landscape of information analytics in BIM is a promising field, but there is a large amount of work that can be done in this space to develop exciting applications that help teams and our industry make better decisions.

Designing for Prefabrication

The promise of prefabrication is nothing new to the construction industry. Beginning as far back as 1624 with the use of a wooden panelized building to house fishing fleets to more of “prefabrication” as we have come to know it with the Aladdin Rendi-Cut homes in 1904, the art of prefabricating offsite has continued to be of interest to builders as a means to build faster and more efficiently (source: <http://oshcore.com/thesisbook/Chapter%201.pdf>). There are many upsides to prefabrication, or “prefab”:

Advantages of a Controlled Environment Work is completed in a controlled environment, where tools, workspaces, and sequence are predetermined, thus making for a safer project site as the use of ladders, lifts, and other on-site equipment is limited and work is performed in assembly line style.

Avoiding Delays Caused by Bad Weather and Other Unforeseen Conditions Production environments are often indoors or covered, so weather or site conditions don’t inhibit the construction process and work can continue to progress in inclement conditions.

Efficiency of Assembling the Parts On Site Although there is debate about the speed of initially constructing the “pieces,” there is no doubt that the speed at which the “parts” can be assembled on site is far faster than site installation. There is a significant time savings in installing parts such as walls, floors, ceilings, and roof elements that come in modular components.

Prior to widespread adoption of BIM, these prefabricated components were coordinated and “sliced” using CAD, which had limitations in fully visualizing how 3D structures were to be built. The advent of BIM has made prefabrication much more dynamic and in general follows this process:

1. The overall building design is completed by a design team and then sent to a fabricator for review.
2. Components of the building are then “sliced” into buildable and, more importantly, transportable chunks.
3. Next they are sent to engineering for material ordering and equipment procurement and sign-off.

4. The building “slices” are then laid out onto assembly lines where the various components are arranged in the most approachable fashion to construct. Often the construction of the pieces follows the project construction schedule.
5. After components are constructed, they are packaged up, numbered, and shipped to the site.
6. Components are then installed on site (Figure 1.17).



IMAGE COURTESY OF GLUCK+

Figure 1.17 Prefabricated project, “The Stack” in New York City

The introduction of BIM into this process allows for design teams to actively participate in the review and design of the modules to be prefabricated. By showing where these slices should best occur, design teams are able to optimize modular units with the fabricator for the layout and sequence of how the buildings’ parts are built and installed.

Future industry speculation in this space alludes to a “print building” button that would eventually allow design and construction teams to send sliced model files direct to the fabricator, where building components can be constructed in near real time. The introduction of large scale 3D printing is a disruptive technology that could significantly impact the way buildings are built. Loughborough University as well as

some private companies such as WinSun have done some fascinating work on this subject.

The ability to “print” building materials such as concrete floors, walls, and roofs on site could change the way structures are made as well as increase the speed (no need to stop at 8-hour days) and the quality (computer numerically controlled CNC) and accuracy of structures, where laborers are acting more in a supervisory and material loading capacity than manual construction.

Coordinating Construction

Sequencing, safety, logistics, material storage, deliveries, quality control, equipment management, and reporting, along with a host of other coordination activities, are what make up a construction manager’s day on a jobsite. Many aspects of this day-to-day coordination use tools that still operate in silos, requiring that contractors input the same data into multiple tools. Currently, this redundancy is forcing many contractors to focus vendor attention on how tools can communicate information better between their systems to eliminate rework. In his book *Profitable Partnering for Lean Construction* (Wiley-Blackwell, 2004), Thomas Cain estimates that in any given construction project there is “up to 30% waste in labor and materials.”

If rework and wastefulness in the construction process accounts for 30 percent waste, the implications for construction consumers are pretty bleak. “Sure, Mrs. Owner, we can build this structure for you. However, we haven’t quite figured out how to make our systems work very well with each other so you’ll need to pay for these inefficiencies.”

This isn’t a very compelling offering.

Imagine if Ford, Chevy, or Tesla Motors sold cars on the same premise: “Sure, we can build you a car. The labor and materials to build it, plus our profit, equals X, but because we haven’t worked out all the kinks in the way our information is exchanged, you’ll need to pay us 30% more.” Would you buy the car? You probably will begin looking into public transportation options in detail.

Unfortunately, this condition is true of much of the technology we use to coordinate construction work. The upside is that there is a tremendous opportunity in the analysis and coordination space to create integrated tools that work together in a real-time manner to better inform decisions and to respond to information more effectively.

Another factor is more tools migrating to the cloud. This is creating interesting methods of tapping into existing data that can be repurposed for other uses. In later chapters, we will go into more detail on companies that are beginning to more broadly understand this need in the coordination space and are developing tools that better enable construction managers to use quality information more effectively to deliver better construction products. Overall, the market seems to be consolidating the number of tools and interconnecting those tools used to eliminate waste.

Using Mobile Devices

The use of mobile hardware in construction has changed the landscape of the modern-day project, in both how information is accessed and how it can be added and disseminated. Mobile technology-enabled platforms are now able to communicate between systems and project stakeholders in near real time. One of the major issues of the past in construction has been the inability for feedback and information flow to come from the field fast enough. Now with many of these barriers removed, teams are collaborating using applications (apps) that ride on mobile platforms such as iOS (Apple), Android, Google, or Microsoft Windows (Figure 1.18). These applications are optimized to perform quickly and have created a new dynamic in efficiency, closing the feedback loop.



IMAGE COURTESY OF LEIDOS ENGINEERING

Figure 1.18 Tablet being used in the field

Additionally, the use of these mobile devices is being defined in different ways. As an example, some teams now employ the use of digital documents or hyperlinked construction document sets. This systems links construction drawings, specifications, submittals, requests for information (RFIs), and other information in PDF form to each other. The value in digital documents is the enhanced visibility into real-time construction information. This all but eliminates versioning control because a team is only able to look at the “latest and greatest” set of information. It is safer to view documents on a tablet in the field because tablet devices can be attached to a harness or safety vest in lieu of large plan and spec sets. Lastly, this example is more sustainable and reduces the amount of printing and the associated reprographic costs.

New costs are associated with mobile-enabled construction, including hardware costs for the devices, application costs (though often much smaller than larger software purchases), wireless or data plans, and staff training. These investments are being made for many construction companies with claims that they are working more efficiently with fewer errors in information exchange and faster response times.

Controlling Schedules

During construction a number of BIM and mobile tools can assist in verifying schedule progress. Usually the key informational needs from contractors during construction are as follows:

- Create and verify the accuracy of the schedules logic
- Introduce detailed sequence schedules to mitigate installation risk
- Manage material and equipment delivery timing
- Manage crew sizes and productivity to align to expected completion timelines
- Use lean scheduling methods to increase productivity between milestones
- Verify work put in place and subcontractors' billing percentages
- Identify root causes that delay or inhibit productivity
- Adjust schedules in real time based on site feedback
- Establish performance incentives/deductions based on scheduled work
- Report to an owner on construction progress and delivery timelines

These are just some of the ways schedules impact the construction process. For many contractors, the golden standard for project schedule controls is Critical Path Method (CPM) scheduling. A significant amount of data points to this type of scheduling method as being largely ineffective in construction. In a recent *SmartMarket* report by McGraw Hill on “Lean in Construction,” the results showed that:

- 86 percent of clients are expecting shortened schedules enabled by a lean approach.
- 62 percent of contractors acknowledge that current practices are inefficient.
- 84 percent of construction managers find that adopting lean has led to higher-quality projects.
- 64 percent of construction managers have improved profitability.

Thanks to statistics like these combined with the economic downturn, many contractors have doubled down on their investment to research other means of creating project schedules. Scheduling methods such as location-based scheduling, or “flowline” scheduling, and Q scheduling, or quantitative scheduling, are leading to a renaissance in construction.

One of the biggest innovations in the creation of construction schedules is the ability to collaboratively develop schedules with project stakeholder commitments in the form of pull plans and lean scheduling methods, enabled by technology such as

Pull Plan and Adept software (Figure 1.19). It's interesting to think that Henry Gantt developed the first Gantt bar scheduling method over 100 years ago. If Henry had had better tools, such as data-enabled tablets and real-time applications, do you think he would've developed something different?

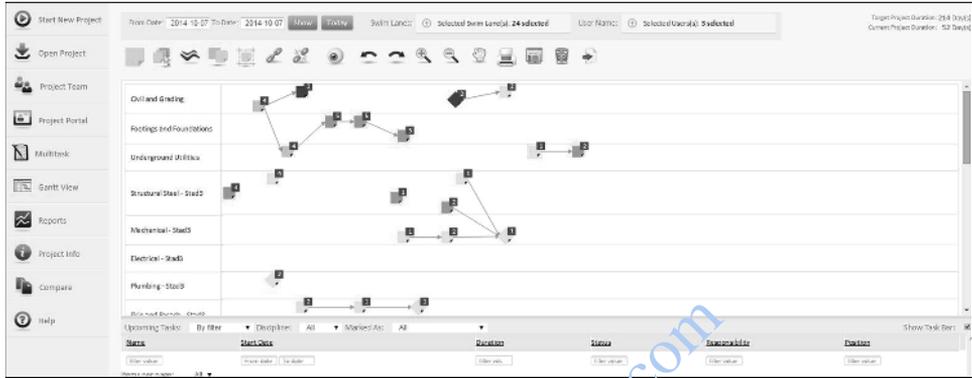


IMAGE COURTESY OF PULL PLAN.COM

Figure 1.19 Screenshot from Pull Plan, lean planning tool

It's hard to say, but we do know that collaboration trends in construction management will not end with BIM. In fact, the rise in collaborative tools continues to expand to other workflows, including estimating and code checking. Specifically, collaborative scheduling has the potential to become much more than a static multipage Gantt chart. Contractors are beginning to understand the value of completing the elusive feedback loop from the field to inform many inputs to financial data, work planning, and safety metrics. Additionally, they are taking advantage of mobile and BIM-enabled applications that allow them to collaborate with their teams better as well as use schedules in a more meaningful way.

Controlling Cost

Understanding project costs and cash flow is the lifeblood of a project. BIM-derived data can be a valuable source of information from a design model to better inform estimates, reduce assumptions, and create a better dialogue early in a project's start. Yet how do we carry the ability to control costs into the field? Traditional methods included the use of multiple spreadsheets, detailed budgeting breakdowns, and usually some methodology of determining a percentage value of installed work.

As mentioned previously, the industry trend of collaboration and real-time input is continuing into cost controls and is creating a shift in input as data and the ability to report from the field begins to trump input from the office. Think about it. Would knowing on a daily basis the percentage of completion a subcontractor is at be useful to control billing and cash flow? Of course! Additionally, initial BIM-derived estimates created for a project are extending into construction as scope budgets are

defined. Some teams are finding ways to continue to connect cost data as construction continues by validating correct billing percentages with custom scope schemas built into tools like Navisworks. Another approach is to use estimating platforms such as Vico and laser scanning to validate the cost of the work put in place versus a visual verification of that in the field (Figure 1.20).



Figure 1.20 Laser scan and BIM overlay

Managing Change

Change in construction is inevitable, or in the words of the ancient Greek philosopher Heraclitus of Ephesus, “Change is the only constant.” In construction, each project is unique. Even prototypical projects will face unique site, jurisdictional, and labor nuances from job to job. Because it is unique, there is no “exact science” to the field of construction. This isn’t to imply that there are no constants in the way the industry goes about building structures. Rather, BIM and mobile technologies have proven that the fundamental systems to construction can be improved upon with applied innovation.

In 2004, Elon Musk took an active stake in an electric car company called Tesla. Many believed that there simply was no way that Tesla could design and create an all-electric car that competed with large automobile companies, let alone build the infrastructure required to support it. However, over the course of the last decade we have seen that Tesla has not only created a car company that competes with Ford, Chevy, and GM, but that other car manufacturers are looking to partner and learn from Tesla. As of 2014, Tesla is worth \$32.4 billion and in many aspects has reinvented how to design and manufacture innovative vehicles.

Manufacturing and construction are similar in some regard. Whereas the activity of starting with parts, available manpower, and equipment is the same, the two quickly travel down divergent paths once field activities begin. Factors include unique site conditions such as weather, permitting, environmental and safety agencies, and other dynamics such as availability of information coming from a design team:

Manufacturing In manufacturing, work commences only after drawings and specifications have been fully engineered, with each part being made to precision in exact quantities that is typically being assembled in a plant. Production is in a controlled environment and efficiencies can be engineered in because of the redundant type of product.

Construction This process is different in construction as often designs are not fully completed and almost always require some degree of field clarifications. The work product is often not redundant and is specialized. Sometimes details are still being worked out, which may affect the schedule, material purchasing decisions, and constructability.

Of course, not every project faces this type of delivery style where the design and construction are concurrent activities. Some projects have the advantage of planning and a thoroughly thought-out design that then carries out to the field. However, in either scenario there will come a point when information is needed and changes need to be discussed and executed in a flexible way.

The way in which information can be managed is where BIM shines. Recent developments in mobile and cloud-based tools now allow us to compare different versions of models to better understand what changed from previous solutions. Additionally, BIM in the field provides a number of significant ways in which it can be leveraged to deliver effective change management strategies that allow teams to analyze potential impacts by using the model for conflict detection, sequencing, and accessibility.

The Closing Construction and Manufacturing Gap

The construction industry is taking more cues from the manufacturing industry, particularly in the area of lean, task management, and flow. Even though there are differences, some of the tools used in manufacturing—such as apps using real-time “line” feedback, prefabrication, 3D printing, and lean methods of communicating—are increasing productivity and changing the way success is measured. In later chapters, we’ll discuss the importance of how teams put systems in place to manage the change process in design and construction and the criticality of clarity in which tools are to be used and why response systems are equally important.

Material Management

Material management begins early in the construction process with design. Typically designers specify certain materials and assembly methods. Then the construction team begins to estimate the required quantities for the various parts and pieces of the project and goes to work getting pricing or bids. Procuring the materials is the next step; material orders are placed, or if there is available inventory from the vendor, the contractor will begin to work out delivery to align to the schedule. Depending on the project, some sites have the luxury of material “lay-down” areas. If they don’t, materials are delivered on site as needed for the construction work to be done that day or week. In lean terminology, this just-in-time (JIT) approach requires additional coordination, but JIT can achieve a higher degree of accuracy and waste reduction if done correctly. Because of the cost and the importance of having materials on hand to assure the continuous flow of work on a project, it is very important that the construction management team understands what is available and where it is located.

The need to track materials that are coming and going into the project site has been addressed by a number of software vendors such as Prolog Mobile and Zebra. Inventory management applications use a standard barcode, QR code sticker, or RFID tag that communicates with a central database to show the current snapshot of inventory on a site. These systems have pros and cons, and it is typically at the discretion of the project team to determine which technology best addresses their needs. There is new technology in this space that is communicating back to the BIM data to verify installation and shade or layer the geometric component in a unique way, thus updating the virtual model to reflect what is occurring in the field in real time.

Tracking Equipment

Similar to material management, equipment tracking is the ability to understand, at any point in time, the equipment on site, what licensed operators are needed, and what safety records or prework procedures are associated with these tools. Equipment tracking is different from inventory management in that equipment may stay on site for the life of a project and there are unique parameters in operating equipment that extend beyond material tracking. Construction managers can use mobile devices to input and collect information about particular pieces of equipment.

Many equipment tracking applications, such as Verizon’s Networkfleet and ToolWatch are available that allow a construction manager to scan a piece of large equipment to access the make and model, load capacities, operations manual, maintenance records, and licensed operators as well as engine diagnostics and fuel consumption. Additionally, personnel can be tracked and managed in the event of a safety issue. One such example is the *hardhat barcoding*—workers scan their helmets into and out of a project site. In the event of an emergency, the construction manager can quickly extract all crew members and take an accurate count of personnel to verify evacuation

is complete. Very little in the way of metrics is available yet, but you can easily see how a tool like this could effectively improve a construction manager's safety program.

BIM also plays a role in equipment management by allowing us to design into the model the right equipment to use and its location. For example, a project site may need two cranes working at different heights. Using BIM, you can integrate equipment lift schedules into sequencing simulations to increase effectiveness and the timing of multifloor or multiphase work.

Closeout

Project closeout is the final inspection and submission of a project that includes the facility itself, supporting documentation, and concluding payment per contract documents. Closing out a project is often an afterthought in construction. This is due to a host of reasons—project fatigue, time constraints, or budget constraints. Properly transferring information to an owner at the end of a construction project is rarely done once the building is completed. In fact, in many cases the information is delivered weeks or months after a project has been completed.

BIM has a unique role to play in the process of closeout. As information becomes more integrated with each of the various systems, the ability to transfer linked and more meaningful closeout information is becoming a reality. Here are some examples of information that may be typically included in closeout or turnover:

- Operations and maintenance manuals
- As-built information
- Shop drawings
- Material lists
- Warranty information
- Other information for life-cycle care

Traditionally, this information has been delivered in hardcopy form and/or as electronic files saved to external hard drives. Recently, construction consumers are increasingly requesting information to be delivered digitally. This is creating a unique discussion among the construction industry as to where the “line” of construction stops and operations start, as well as what liability can be associated with delivering an as-built BIM. Largely, the answer has been that owners are starting to see the construction team as the logical steward of their information throughout the construction process in regard to as-built information and other installation records.

The formats being requested are changing as well. Many owners face constricting operations budgets. Because of the need to deliver better turnover data, contractors are using this as a point of differentiation in their businesses to make a more compelling value proposition versus their competitors. Many are doing exciting work in defining what the “as-built” of the future may look like, which includes an

artifact and constant component to it that we will cover further in Chapter 7, “BIM and Close Out.”

Punch Lists

Punch lists are a checklist of items that must be completed in order for a construction project to be accepted by the owner in order to receive final payment. To get to an as-built, you have to first be able to manage the completion of the work. This means details. The details of punch lists span not being able to start up an HVAC unit (commissioning) to paint chips on the corners of walls. The challenge is in managing the information around punch lists. Applications such as BIM 360 Field and Prolog Mobile allow users to mark up plans on their mobile devices and identify areas that need to be repaired before the contractor’s work is marked as completed. Additionally, the use of the BIM model is becoming increasingly useful as these plans can quickly become congested, and thus the use of the model to mark in three dimensions exactly where an issue is can save a significant amount of time (Figure 1.21).



Figure 1.21 Model punch list callout

Construction management teams spend a lot of time resolving punch list items in the field. The efficient closeout of a punch list can allow contractors to get paid faster, turn over buildings earlier, and mitigate the time “wasted” in managing spreadsheets and manual plan markups.

Managing Facilities

Construction consumers continue to become more informed. In fact, the number of owners requiring BIM on over 60 percent of their projects surged from 18 percent in 2009 to 44 percent in 2014 (Figure 1.22). The main driver for owners requiring BIM was reduced errors and rework. Additionally, many owners are now requesting that construction managers deliver as-built information in both hardcopy and digital

formats. Some progressive owners are requesting that the information they receive be formatted in a way that can be seamlessly integrated into their computerized maintenance management systems (CMMSs) and/or facility management (FM) systems as part of the project turnover effort. Both CMMSs and FM systems involve managing the operations and assets within a facility effectively to ensure its continued use and can represent up to 85 percent of a facility’s total operational costs (Figure 1.22). This trend addresses the risk owners face when given large volumes of hard or static data that needs to be manually input into their maintenance and operational systems.

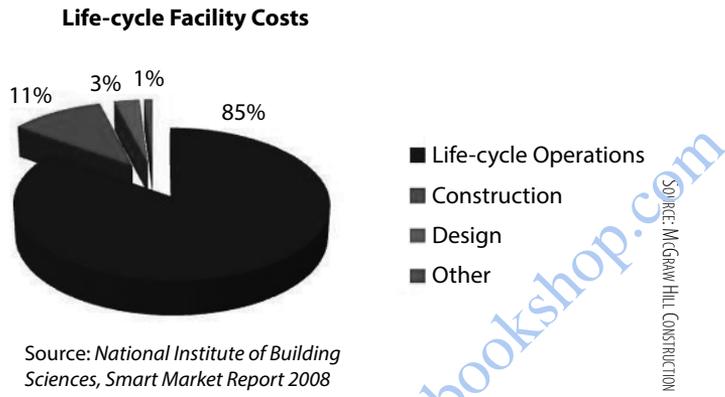


Figure 1.22 Life-cycle facility costs

From the owner’s standpoint, the current turnover process creates significant risk in the form of delay in successful operations. For example, if an owner receives the project turnover data at the end of a project and the first day of use, the facility and operations team’s work is just beginning. They now must input this information into their systems to begin operating the structure. This may include changing filters, oiling equipment, replacing damaged equipment, or keeping items under warranty with accurate records. If it takes the facility manager 3–6 months to input this information into a CMMS or FM system, what has been missed? What hasn’t been maintained? And what is at risk of falling out of warranty? These are the real issues that face a real estate asset holder in regard to new construction.

To address this knowledge transfer gap, construction managers are becoming more adept and knowledgeable about how to deliver information into the owner’s systems at the end of a project. Chapter 7 describes an innovative approach to creating an improved deliverable for a customer.

Knowledge Platform Population

One of the areas growing in importance is the ability for a team to collect and aggregate best practices in a central location that is accessible by a company’s

associates. These hubs, or knowledge management platforms, are typically web-based tools that allow users to input and search for information about an array of topics. Knowledge management platforms include best practices, innovations, case studies, and tutorials. In many cases, this knowledge base increases the value of a company and the quality of an associate's tenure there, making a company a better place to work.

As it relates to technology and BIM, many companies are uploading video tutorials, which share a user's screen to eliminate the creation of BIM/CAD standards that were traditionally hardcopies. The use of brief video content and knowledge sharing libraries is consistent with the trends of attention span, time commitments, and content absorption related to information finding. Based on metrics from the National Center for Biotechnology Information, US Library of Medicine, the average attention span for a human in 2013 is 8 seconds (Table 1.1).

► **Table 1.1** Average attention span statistics for 2013

Attention span statistics	Data
The average attention in 2013	8 seconds
The average attention in 2000	12 seconds
The average attention of a goldfish	9 seconds
Percent of teens who forget major details of close friend and relatives	25%
Percent of people who forget their own birthdays from time to time	7%
Average number of times per hour an office worker checks their e-mail inbox	30
Average length watched of a single Internet video	2.7 minutes

Source: National Center for Biotechnology Information, US Library of Medicine

If viewers believe the information to be valuable, they will dedicate their attention span for longer but rarely for more than 10 minutes total. Because of this reduced amount of focus amid other time commitments throughout a day, we see that many companies have opted to create 5-minute or less videos to describe a goal, workflow, or software function.

Ultimately, knowledge management platforms are used to address many industry challenges, which include:

- An aging workforce, with years of valuable experience and knowledge that can be captured
- New hires' ability to learn and gather information quickly to be up and running faster
- Improvement of a company's overall shareholder value
- Engagement capabilities that allow users to post, share, and refine information in an enterprise

- Reduced commitment in the creation of company standards or process that may change due to new technology
- Faster creation of content as there is less effort in speaking over a video of a live screen environment than typing content

The knowledge capture feature in firms continues to become more valuable as research and development or pilot initiatives are identified and can be used as a means to improve and engage a workplace.

Where the Industry Is Headed

The construction management industry as a whole is headed toward a results-focused toolset that is connected, collaborative in nature, and mobile ready. Although the industry has largely accepted BIM as a useful tool and an improvement to construction management, there are still processes and behaviors beyond the technology that need to be addressed when looking to integrate BIM or to improve on the current condition.

Leadership Buy-In

One of the main issues when BIM first became available to construction managers was the question “Will BIM last?” Of course since publication of the previous edition of this book the answer is clearly a resounding yes. However, challenges remain for some construction management firms on the leadership side. These challenges are in the form of understanding the value, customer needs, or the costs and return on investment for BIM. This can be due to a number of reasons. Sometimes it’s a lack of training on BIM and what it is capable of. Often the ability to explore new tools is limited due to time constraints, where many executives simply don’t have the time to check out new tools and processes that may affect them.

With BIM adoption at 70 percent in the United States and growing quickly in other countries per McGraw Hill’s “The Business Value of BIM for Construction in Major Global Markets” (p. 8), it is probably safe to say that the majority of firm owners are now aware of BIM compared to five years ago. It is also now becoming an industry norm, whose usefulness is being defined in a number of ways. Just as different firms specialize in building different structures, with different staff and project types, the use of BIM is being applied in different ways that are geared more specifically to those projects. As an example, road and bridge infrastructure projects tend to use less of the functionality geared for vertical construction, such as clash detection and multi-trade coordination. Rather, they tend to use BIM for estimating takeoff, sequencing, cubic yards of cut and fill, and layout, as well as importing laser scans to verify installation accuracy. Another example occurs within vertical construction itself such as the tools required for a school versus a hospital. The needs and complexity of each project type differ significantly.

Because of the unique needs and benefits that BIM and technology can offer a construction management company, it is the responsibility of the team as a whole to define and communicate what they see as valuable and adopt these tools, as well as have a strategy in place to analyze the construction technology space to identify new or improved tools that could further increase their efficiency.

The Evolving Role of the BIM Manager

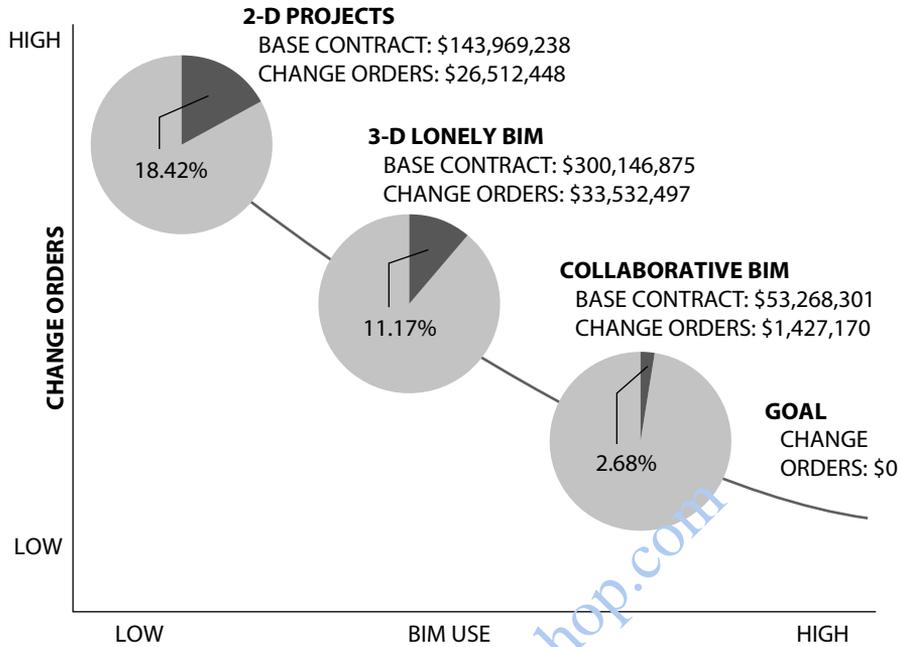
The role of the *BIM manager* has evolved in construction management. For one, teams are becoming more educated. The number of tech-savvy graduates entering the market who have had advanced exposure or training in BIM tools, combined with current users who are more project experienced, is creating a shift in the use of BIM in construction. Although many firms began with a BIM manager role as a single source of responsibility, we are seeing a shift in dedicated resources to firms now integrating BIM as part of the responsibility of the project team with no dedicated BIM specific staff member. Some projects large enough in size to support a dedicated BIM manager often utilize this resource to the fullest extent. Other firms, whose business model is more diverse, may centralize resources to spread the BIM resource across a variety of projects. Although the strategies of technology and information management in the construction process vary from project to project, details such as project size, budget, and staff availability remain the main factors affecting the decisions and strategy for BIM integration.

At a company level, many construction management firms have shifted BIM-specific personnel into more general technology personnel at a companywide leadership level who consistently seek to understand industry trends and customer needs, identify needed business improvements, and seek out opportunities to increase profits and innovate. There is no hard and fast rule as to where these professionals come from; they often have varied backgrounds. Some come from information technology (IT), project management, software vendors, or BIM. Regardless, construction firms are putting these focused resources in place to manage strategy and deliver technology at a company level as it continues to become more critical to the way construction is delivered.

What Have Been the Results?

The return on investment of BIM has always been somewhat of an elusive metric to capture. However, current data strongly suggests that the introduction of BIM processes and technologies is changing the construction landscape to be more productive with less risk and less in-field changes (Figure 1.23).

Some of the intangibles of BIM and technology are hard to make quantitative. Additional benefits have been increased communication due to more collaborative environments, better information loops from connected applications, virtually connected workspaces, and enhanced capabilities. BIM continues to be built upon as the construction industry finds new ways of using the information available.



SOURCE: J.C. CANNISTRARO; MCGRAW HILL SMARTMARKET REPORT

A study by J.C. Cannistraro of 408 projects valued at \$559 million shows how, in the big picture, BIM saves money as the team gets more collaborative.

Figure 1.23 BIM-related savings as collaboration increases

Summary

The purpose of this book is to look at BIM and how it continues to change the way we deliver construction. Just as important to BIM as a technology is the journey that BIM has put our industry on. Our industry was in need of reinvention that included technology improvements and enhanced collaboration. Status quo no longer defines a successful contractor. Construction firms around the world continue to realize the benefits of BIM as well as the ancillary features of better methods of sharing and coordinating information.

So is this it?

We don't believe so. In fact, we believe that this is just the beginning for the technological renaissance that is surging within the construction community. Ultimately, the questioning, analysis, and resulting innovations continue to offer exciting opportunities to improve our industry and deliver further on the promise of BIM.