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BIM

changing the construction industry

CONFERENCE PAPER | Scheduling, Estimating, Construction | 19 October 2008

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Abstract

Documentation has been a necessary component to project work throughout history. However, there has been a paradigm shift in how people communicate through documentation, from paper to electronic forms. Product development and manufacturing have long relied on drawings to communicate, and as those drawings have migrated from paper to CAD, the effect on the development and manufacturing processes has been profound. The construction industry is beginning to see a similar shift in the fundamental area of construction documentation and the associated processes. The change comes in the form of a collaborative computer-based environment referred to as Building Information Modeling, or BIM. BIM offers significant value in terms of collaboration and value throughout the construction process, from the initial design phase, through estimating, scheduling, and project management. However, BIM is not receiving the same enthusiastic welcome by every part of the industry. The education sector has traditionally been an incubator of new technology and, with some reservations about how BIM is implemented in the curriculum; it is gaining popularity on many campuses. But industry acceptance of BIM is reminiscent of the CAD technology a generation earlier. Viewed as unnecessary by many, familiar and reliable methods are often preferred over something new. But as owners begin to demand the use of BIM, and the value can begin to be demonstrated, the spread of BIM's use throughout the industry will have a very profound effect on nearly every part of the construction process.

Introduction

When a group of individuals work together on a project, communicating specific characteristics of that product or idea, from one person to another, requires documentation of these specifics. Such ideas could simply be spoken, but it is well understood that the reliability of spoken words is limited and can result in miscommunication. Physical documentation has existed for centuries for this very reason, and, for most of that time, such documentation has been created on paper. However, in the modern world, words on a page have been largely replaced by electronic versions of themselves, whether it is an email, a webpage, or some other format of an electronic file.

Similarly, for product development and manufacturing activities, what had traditionally involved putting pencil to paper to create two dimensional drawings, thus communicating the details of the product, has also been replaced by an electronic drawing, usually created with computer-aided design, or CAD. The term CAD appears to be an understatement in itself. "Computer-aided" may suggest to some that the computer is merely an aid in the design process. Perhaps it was when CAD was introduced, but today the computer exists as the central piece of the process, every bit as much as the paper was for centuries before. Surely the term is a hold over from the past, hinting at the limited degree to which computers were actually aiding the design process in those early years of the new technology. However, what started out a generation ago simply as CAD evolved into a more comprehensive approach, often referred to as modeling (Jabbour, 2006).

The modeling approach to design was found to integrate well with other engineering and manufacturing tools known as CAE (computer-aided engineering) and CAM (computer-aided manufacturing). These tools help to develop a product and more efficiently manufacture it. But looking at the ways in which that new technology called CAD was adopted a generation ago by product development and manufacturing, and seeing how it then evolved into a modeling process, we can begin to see a similar pattern in the construction industry that involves a new tool referred to as BIM, or Building Information Modeling.

BIM is more than a new tool for the construction industry. BIM represents a new, collaborative environment in which the project team can work (Dietrick, 2007). It begins with the architects and engineers, but when fully utilized, it involves the entire project team, including the contractor and the owner or end user of the building. With the BIM tools that are being marketed today, the construction industry is beginning to make some very fundamental changes, not just to the way construction projects are "drawn", but how they are analyzed, estimated/budgeted, scheduled, and managed, from conception to close out, and beyond.

BIM and the Construction Process

Design

As the architect or engineer (A/E) completes a new design for a construction project, it is handed over to someone who will have to build it. The A/E has attempted to put every detail regarding that project on the two-dimensional drawings, any additional renderings, and other construction documents. Inevitably, some items are omitted or other errors are made. In fact, the quality of these construction documents has been cited as a significant issue in the construction industry (Larrick, 2007). At this point, what traditionally happens is the construction personnel discover the errors or issues and they will have to reconcile them with the A/E. This can be an iterative and time consuming process as the design is further developed and defined. Other reasons for changing the design exist as well, such as the owner making changes to the project. These changes are often due to the owner's need to physically see the project before deciding on some of the details. In any case, the risk to the project's cost and schedule at this point in the process is based on these changes not being discovered until after construction has begun. At that point, changes are a direct risk to the cost and timing of the project. These types of issues at the design phase can be minimized when modeling in the BIM environment, as BIM offers some very distinct advantages.

As a building design is developed with BIM, or modeled, the construction personnel can be brought in as part of the process at a much earlier point in the project. Instead of waiting for the A/E to complete the design first, the contractor can begin to identify constructability issues in the building model on a real time basis rather than an iterative "hand off" process (Dietrick, 2007) that can waste a significant amount of time. This real time development of the building model can save time and money later in the project lifecycle. In response to the issue of owners making late changes, based on physical sight, most BIM tools offer a very high level of visualization features. The ability to see the building in three dimensions, not only from the exterior, but to actually "walk through" the building model early in the design stage helps ensure owners are seeing what they want and are satisfied with the design. The owner no longer has to wait until construction has begun to "see" what it looks like. The risk of making changes later in the project is again minimized through this ability to visualize the project early in the design process. When the building model is completed with this amount of collaborative effort between the A/E, the owner, and the contractor, the result is a more robust design with minimal risk of changes at the time of construction (Dietrick, 2007).

Another way to demonstrate the advantages of working in the BIM environment is to consider the lessons learned, or project review process. Throughout any project cycle, there are a number of "lessons learned". Good project management skills would dictate that these lessons learned be disseminated throughout the organization and applied to future projects for their benefit. However, many lessons learned are specific to the particular project, and therefore do not necessarily apply to the next projects. But when operating within a BIM environment on a project, most lessons are learned from the virtual construction process before any ground is broken. Instead of struggling through real issues with cost and timing implications, the issues are discovered in the virtual project where they can be addressed with an optimized cost and timing solution. When the physical construction does begin, it is as if it were the second time going through the project, but with the benefit of already having the lessons learned (Ivanikiw, 2007).

Estimating

Assuming a standard set of construction documents, one of the next steps under a traditional construction project would be for the construction manager to prepare a detailed estimate. Putting together a reliable estimate has usually involved a person with the skills and experience to pull together reasonably accurate estimates in a reasonable time. It is not cost effective to count every brick, bolt, or beam in the building, so estimators with the skills to balance these aspects of the estimating task are valued in the construction industry. However, in the BIM environment, estimating is a simpler, easier, and more accurate exercise (Dietrick, 2007).

From the start of the project, the building is modeled within an object-oriented environment. This means that building components are not just drawn to look like a certain object, but rather they are recognized as that object throughout the BIM process. For example, a structural beam is not simply drawn with a few lines so as to look like a beam. Rather, the beam is placed as a three-dimensional object, recognized as a beam by the BIM software, and complete with all the physical parameters that make up a beam such as length, width, height, and weight. Along with the physical properties, there is the opportunity to attach various metadata to an object that will continue to be associated with that object throughout the project. In the end, the software recognizes exactly how many beams are in the building, all of their sizes, and any other cost, sourcing, or other data attached to them. Using the building model's actual data is a very different approach to creating an estimate when compared to using a quantity take-off that relies on an estimator identifying all the correct components on each sheet of the architect's construction documents.

Again, BIM bridges a traditional gap between the architect/engineer and the construction personnel. Even if the A/E is using a three dimensional CAD package to design the building, without using BIM he would have to "dumb down" an extensive amount of that project's information to a stack of paper and hand it off to the contractor (Dietrick, 2007). Working in the BIM environment allows not only the collaboration between the A/E and contractor, but preserves all the information that went into the building model as it gets transferred to subsequent parts of the construction process.

Of course the owner is a likely participant in this process as well. Through such collaboration, the owner now has some unique opportunities in regards to costing and scoping the project (Dietrick, 2007). It becomes relatively simple to make a change to the building model and observe how that change impacts the total cost of the project. An example may involve analyzing a change in one area of the project to determine if the project could then be expanded in another, thereby offering the ability to align the design to the budget. Many of these cost and scoping opportunities are facilitated through the BIM environment.

Scheduling

As designs are finalized and estimates are created, it becomes necessary to plan the schedule and determine which tasks will be performed at what time and in what order. Traditional scheduling methods rely on a few people familiar with the tasks to be performed to make the schedule. These members of the project team determine how long each task should take to complete, and in what order they need to be completed. They must also include any other associated logic or precedence between the tasks. As technology has developed over time, this scheduling process has been transformed from an all-paper process to one involving scheduling software, not unlike other forms of documentation mentioned previously. However, the schedule is usually not dynamically linked back to the building design. It relies on those who created the schedule, through analysis of the building design, to make any changes or updates to the schedule if and when the design changes. This is perhaps one of the more significant gaps in the traditional process that is bridged through the use of BIM.

Consider the building model in three dimensions. The time component is generally referred to as the fourth dimension. The schedule is essentially the result of assessing the work tasks as they relate to time, both in duration and sequence. Going back to the design phase of the project, another key feature of most BIM packages is the ability to relate sequencing of objects within the building model. Along with the components of the building being managed as objects within the model, there also exists the concept of sequencing that relates which object gets placed in the model before or after another. As an example, assuming that the building's steel structure has to be erected before the floor can be placed, the sequencing of these objects is included in the model. When this sequencing is applied to all the components throughout the model, it becomes the underlying logic that feeds the schedule. The project team no longer assembles the schedule. Instead, it is one of the many results of the BIM model. Now collaboration between owner, contractor, and architect/engineer can also include the schedule as one of the project pieces being optimized. A change to the model can immediately return not only the cost implications, but also the effect to the schedule. The owner can decide very early in the process what cost, time, quality, and scope trade-offs can be made.

One of the more impressive visualization tools offered through many BIM packages is the ability to view an animated model of the construction process taking place while the schedule scrolls across the bottom of the screen (Dietrick, 2007). This feature provides the project team a very powerful four-dimensional representation of the project. Beyond its obvious appeal as a presentation tool, such 4D models can be used during the construction process to assess project status, compare actual progress against scheduled work, or to visualize a look ahead. At any day on the schedule, the team can see what the building should actually look like and at what level of completion it is, from any point in or around the building. It becomes quite obvious how powerful a tool BIM can be when the duration and sequence of the tasks are applied to the model to produce a schedule for the project.

Managing the Project

Once construction has begun on a building, managing that project is a process that consists of monitoring the progress, comparing the status to the schedule, and directing project activities so as to remain on schedule. Several challenges to this process have traditionally presented themselves. The most common of these challenges come in the form of changes. Changes that are caused by issues not previously discovered or resolved, design or scope changes by the owner, or unforeseen conditions are all possibilities. Claims and disputes are largely an accepted part of the construction process, but it is also generally agreed upon that such changes lead to wasted time and money. This is true not only from the owner's perspective, but of everyone involved. It certainly costs everyone in terms of time, and it usually results in costing someone money. All such issues seem to come down to a misalignment between the status and the expectation (Willard, 2007); between what was thought to be the case and what really is. What BIM offers the project team is the possibility to minimize these issues. The BIM environment helps ensure that all issues have been discovered and reconciled at an early stage of the project. The chance of having an unmet expectation is significantly reduced. This has the direct effect of reducing the number of claims and disputes, and the wastes that are associated with them.

Operations

Up to this point, the focus of having the building modeled and conducting the construction process in the BIM environment has been on the efficiencies that can be realized throughout that process. However, after the construction is complete, BIM continues to offer advantages to the owner in regards to the ongoing operation of the building. Instead of the traditional set of manuals that attempt to document the building's electrical and mechanical systems, the same building model that was used in the construction process can be provided at the project close out. This provides the owner with any and all information about the building systems. The owner could then use this information for many purposes, such as implementing an automated approach to building maintenance, or analyzing equipment layouts in a plant for efficiency improvements.

Acceptance of BIM

BIM is one of the most significant new tools to arrive on the construction scene in the last generation, and it is gaining an increasing amount of attention in the industry. When CAD was initially introduced, it was seen by most as a tool that was not much more than a computerized means to a two-dimensional drawing. But CAD eventually proved very useful, evolving over time from drawing to modeling, and bringing into existence CAE and CAM tools that collectively were a much more efficient method to developing products (Jabbour, 2006). Most would agree that CAD/CAE/CAM tools are now enabling engineering feats that would not be possible without them. BIM is following a similar pattern.

BIM takes the traditional paper-based tools of construction projects, places them in the computerized environment, and then facilitates a level of efficiency, communication, and collaboration that far exceeds those of the traditional construction processes. Perhaps the most important of these is the level of collaboration that is facilitated through the BIM environment. The construction industry is moving in a direction that has resulted in an increasing number of collaborations and partnerships, particularly on larger projects. This industry trend suggests that those who can achieve a high degree of collaboration will hold a competitive advantage in the market. BIM will be feeding this trend towards collaboration, and most in the industry will find that these partnerships would simply not be possible outside of a BIM environment.

Even though the use of BIM in the construction industry is growing rapidly, not everyone has embraced this new tool (Rubenstone, 2007). People have a natural tendency to resist change, and those in the construction industry are perhaps more prone to that resistance than others. Because BIM represents such a significant change in how projects are run, some established members of the industry are naturally resistant to its adoption. Working in such a new way is a challenge. So many of the work processes have been developed over time to a point that people are only comfortable working in that one familiar way. For these people to then switch to working with a model of a building, as much as the model is superior to the paper drawings, seems to leave many with a feeling of less control. Where people were accustomed to anticipating issues in the construction process, they continue to look for such problems on site when such issues did not exist in the model. With BIM, there appears to be a learning curve associated with the notion of trusting the model (Cramer, 2007). It will take some time for people to accept that if the issue does not exist in the model, and the project is being executed according to the model, then there will not be an issue on site.

Another reason that new technologies such as BIM often meet resistance is based on a difficulty in demonstrating a return on investment with the new tool. Unless clients are asking that this specific tool be used on the project, it becomes difficult to justify an investment in its use. The value that the new tool brings must be demonstrated. In some cases, BIM is being viewed in the industry as a sort of toy for the younger generation. As if those who came from the video game generation just can not seem to separate work from play (Rubenstone, 2007). But slowly it is being recognized that people are performing real work and achieving real results through the use of BIM (Rubenstone, 2007). How this will be shown as having a positive return on investment has yet to be seen. But BIM is far from an all or nothing tool. There are various levels of BIM implementation, and that will allow different users to get into the BIM environment as slowly as they wish, and with a corresponding degree of investment (Dietrick, 2007). As the tool shows its ability to produce value for the company, the investment can be increased to a higher level.

As is the case with many new technologies, BIM is also gaining a foothold in the industry through the academic world. Companies who provide BIM solutions, the actual software, are heavily involved at the university level. They are promoting BIM solutions to those they see as the future users in the industry. The level of support that has been observed is an investment for these companies, but it appears to be one that may pay off, as the next generation of architecture, engineering, and construction professionals is quick to see the implications and advantages of this tool in the future (Rubenstone, 2007). Students in many programs are increasingly requesting courses in BIM as they see it as being a part of their future career. But there is still some caution on the part of the academic institutions. They want to ensure that the students still learn the basics, such as traditional drafting, before abandoning the basic skills for the higher technologies. That seems to be the approach that was taken when other new technologies, such as CAD or FEA (finite element analysis), were introduced to traditional curricula in the past (Rubenstone, 2007).

Ongoing Issues with BIM

As much as BIM is the next great enabler to successful construction, it is not without issues. From its conception, it was recognized that one of the biggest issues to address in an industry of varying BIM packages was interoperability (Moura, 2007). As a building model is created in one software package, there is no guarantee that everyone else downstream in the construction process will be using the same software package. It is actually quite likely that different architects, engineers, contractors, and major subcontractors will have different software packages. For this reason, interoperability has been one of the primary goals of most BIM providers. As the tool continues to evolve, providers of BIM software are seeking the input of its users to define what feature they feel will be required and the most useful. Although there is general consensus on some of the major pieces, such as creating documents and maintaining an object-oriented model, many features may be of varying importance to different users (Sawyer, 2007). Ideally, any model can be brought together into the same space as another model and an analysis of the two completed, regardless of the software in which each of the models was created. Although many offering BIM solutions are claiming to be compatible with other model formats, the potential for issues always exists. Whether it is a matter of absolute compatibility or just an issue of efficiency when moving from one BIM package to another, how this issue of interoperability affects the adoption of this tool throughout the industry has yet to be seen.

Conclusion

Building Information Modeling is a very significant change coming into the construction industry. It is more than just a new technology; it is a new environment in which to work. Its most valuable offering is the way in which it facilitates a degree of collaboration that is unprecedented in the industry. It is reminiscent of CAD and its associated tools when they were introduced a generation ago. At this point, the construction industry is viewing BIM as a new tool in much the same way. Some see it as just another tool with limited real value, while others see it as an enabler to change. Such a change may be the most significant the industry has seen in many years.

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