chapter

1

Introduction to Building Information Modeling

Building information modeling is most often referred to as BIM. In practice, BIM is defined as the file that is created by the use of three-dimensional (3-D) computer-aided design (CAD) software programs. Unfortunately, this is the broadest definition and is often the root cause of failure in the deployment of BIM. The focus on BIM as being an "upgrade" to the latest CAD software is the first step many firms take in the wrong direction. In reality, BIM is a process improvement methodology that leverages data to analyze and predict outcomes throughout different phases of the building life cycle.

While there are several books in the marketplace addressing the technical aspects of BIM, including software training manuals, the focus of this book has been to look at BIM from a building owner's perspective. To date, the owner's role in BIM has primarily been as the recipient of the "BIM" at the end of the project. The reality is that the owner is the most pertinent participant in the BIM process. This book is not intended to be a technology-driven perspective of BIM but rather a tool for an owner to better understand BIM in order to deploy practical initiatives that lead to BIM being beneficial for the owner's projects.

BIM is a "paradigm shift"—and, in most cases, a paradigm shift happens quickly. For various reasons, however, the architecture, engineering, and construction (AEC) community is moving through this shift at a much slower pace. The major reason for this lethargic adaptation is due to the nature of the construction system at large. It exists as a highly fragmented environment, supporting an ecosystem consisting largely of influencers that consist of highly repetitive experience with a single decision maker— the owner—with relatively nominal experience compared to the ecosystem. The current state of the AEC processes and the end state of the paradigm shift are both well understood. The adaptation from the current to the end state is creating the most chaos. It is important to understand that the notion of BIM as a process improvement technology is more conceptual than analytical. To deem an improvement of process implies the measurement of existing systems and documentation of these metrics as a baseline for improvement.

BIM instills a vision of what the future of construction can become in terms of "hard" improvements. BIM is also an essential platform today to measure and collect data for existing process metrics. The single mission of this book is to engage with the *most* experienced stakeholders in the AEC industry. Software is just a tool and, like many tools, is misused by practitioners with the *least* amount of experience.

The information age has created a platform for transparency in almost every industry, except the construction industry. The challenge has been the ability for the "consumer" (in this case the owner) to drive and demand change.

This book covers both basic and more complex BIM topics. It also incorporates a blend of management consulting and technology principles. It is meant to be used either in parts or in its entirety, based on the needs of the owner. This book contains a lot of content and concepts that are meant to drive awareness for discussion and not necessarily for practical implementation. The majority of the book is derived from years of practical experience in the field. Many practical examples are presented in this book in a special feature called "A Tale from the Trenches."

The purpose of these tales from the trenches is to demonstrate specific workflows along with the challenges and benefits of using BIM. These were developed from actual projects but modified and made anonymous so that there is a clear and honest insight. One of the single most important challenges within the AEC community is

honestly regarding the actual utilization of BIM and the challenges associated with BIM implementation.

In many chapters, there are quotes from other books that are relevant to the subject matter. These should also be considered recommended reading for your organization.

The purpose of this book is to provide a framework for building owners and developers to drive BIM objectives that substantiate their objectives and guide their AEC vendor community to compliance. Much of the information about the methods of the AEC community at large provides a baseline for how BIM is being used currently and are not necessarily best practices. Owners can demand a better process with greater transparency if they truly understand the opportunities and limitations of the technology, the industry, and the future. This book can be read from beginning to end but is also designed to be used as a reference for owners that are facing a particular challenge.

Technology should drive benefit to the consumer. Prior to the Internet age, a consumer went to a travel agent to book travel, hotels, and rental cars. There was no transparency of flight schedules, rates, availability, and quality. The travel agent acted as a proxy of the consumer to fulfill his or her needs but was compensated by the travel industry. Consumers were required to "trust" their travel agents. The rule of thumb "to trust but verify" was difficult because there was no method of verification. Technology made it possible to shrink the sales channel and disintermediate the supply chain. Consumers were given the ability to both trust and verify the pricing and availability from their travel agents.

The AEC community and the construction industry at large are built with layers of agents that may or may not create value for the owner. In many cases, as in the case of many general contractors, the value may only be the subordinated risk of contracting with a single party. This is of value to many owners, but the value may not be justified by the price. In lieu of purely subordinating risk, an owner should be able to mitigate risk by leveraging data. This type of data is generally referred to as decision support data and is common in most other industries.

The History of BIM

One of the most vivid statements I remember from my father was that the most intelligent people in the room are the ones who are silent. I have really used this in understanding "why BIM matters." I have

found that the discussions around BIM tend to be driven vocally by those in an organization who "know it all" but have never actually built a building. The experienced people tend to remain silent—or, better yet, bored. The most experienced professionals in our industry understand that the success of any technology is driven by the weakest link in the ecosystem. For a better understanding of this, refer to the history of BIM. This, to the dismay of many of my peers, is to ignore the technology aspects of BIM in its entirety because BIM is a paradigm shift, and it is much more than technology. Instead, I have focused on spending my time with the most experienced individuals in the construction industry. This time is spent trying to understand reality versus fiction.

The start of design documentation was the creation of a new language to communicate the three-dimensional (3-D) world (reality) in a two-dimensional (2-D) communication platform. This platform was the first in creating a language in 2-D that could be universally understood. This 2-D platform consisted of plan and elevation views with a level of development (LOD) that was communicated with details, sections, and specifications.

It was also clear that in this 2-D platform there would be gaps in information that would be subject to interpretation. Because, realistically, how could the real world be communicated in a 2-D document? The phrase "do not see the movie, read the book instead" has been heard many times by most individuals. The book leaves so much for our own individual interpretation (and imagination) that reading becomes a highly individualized experience. Conversely, the movie is very specific, and we tend to stretch to develop our individual interpretations of the movie from our own experience. This may work in the entertainment world, but in the world of construction, interpretation leads to so much variability that expectations are hardly in-line with each stakeholder. This interpretation is obviously biased—not only by each stakeholder's role but also by budgetary concerns.

BIM software by definition is a subset of CAD software, but BIM processes are very different from CAD processes. The traditional process of developing construction drawings began by using mechanical methods (pen/paper, ink/vellum, etc.). With the advent of CAD, this mechanical process was moved to the computer screen, where it was transformed into a computing process. The deliverables remained unchanged, but the speed and precision those computers were able to bring to the development of construction drawings was

accelerated. Additionally, the rate of incorporating design changes was vastly affected. Therefore, the design process was not affected by this technology as much as the production process. This is directly analogous to the change from a typewriter to a word processor program on a computer. CAD provided some design-assist tools that allowed for precise dimensioning, easy editing, and cut-and-paste functions. CAD has historically been used as a design authoring tool.

As a result of the increase in computing power and the decrease in price, many in our industry have come to use CAD to collaborate during the design process. With the advent of easy-to-use Internet-based file-sharing technologies, the AEC industry has become fairly efficient during the design phase. These CAD programs have also been capable of producing 3-D CAD models for the purposes of visualization. Additional applications were developed to extend basic CAD functionality to link this information to databases and automated routines (scripting macros). Traditional CAD, however, has played a very minor role in optimizing the overall construction process. To say that BIM is "just another CAD program" would be the equivalent of saying that computer spreadsheets are "just another calculator."

The current standard of construction documentation is interpreted to build the "reality" 3-D model (i.e., the building), while BIM is used to create a "virtual" 3-D model to build construction documentation (CDs). These CDs are then interpreted and used in a traditional construction process. In essence, today's construction environment sees BIM being used as a CAD application. This process is changing quite rapidly and being mostly driven by owners and contractors. CAD is used to develop information that is used in the life cycle of the building which is then aggregated into the building. BIM is used to develop an aggregation of building information that is then extracted throughout the life cycle of the building.

In summary, BIM is a database-driven representation of the building throughout the building's life cycle. While 3-D is an important part of BIM, it is only a small part of its capability.

The construction industry moves at a very deliberate pace. While this pace may not seem aggressive, it is indeed progressing. The goal of this book is to provide a guideline for owners to create a plan that is evolutionary and iterative in nature. It is easy to know where owners are (as-is condition) in comparison to where they need to be (to-be condition) in a paradigm shift. The challenge is all of the steps in between. These are analyzed through a process called gap analysis,

and I will explore these concepts—as well as how to apply these tools—in later chapters.

BIM can be broken down into different but similar database sets that are based on the author and use of the information:

- Design intent model (by the designer for the designer)
- Build intent model (by the contractor for the contractor)
- Fabrication intent model (by the subcontractor for the subcontractor)
- Facility management model (by the owner for the owner)

Most new systems are first misunderstood and then misused, which consequently results in poor outcomes that are soon after dismissed. Due to the similarity of information, there is a belief that information created by the designer for the designer will somehow be useful for the contractor. The management of building data is a role that is commonly used on large projects. With the advent of BIM, it is becoming a necessity on projects of any size. The amount of data created by BIM is (at a minimum) tenfold that of typical projects using 2-D plans and specifications only. Simply managing data is now becoming a full-time job.

BIM is a transformative technology, very similar to the Internet. Much like Internet adoption, it is initially being used to automate known workflows and legacy information. As this technology becomes better understood, it will soon be used to change and improve construction processes. Fundamentally, the owner community has not benefited from the information age, while the advent of technology has created a high level of transparency to the consumer. BIM is changing the owners' processes and shaping the way they do business.

Future Trends

Discussing future trends prior to current trends may seem counter-intuitive, but the future opportunities of BIM will spur the current investment required to take advantage of these future trends. Current BIM adoption and use is on a project basis for managing and driving successful project outcomes. The most interesting aspect of BIM in the long term is the application of data mining and analysis. Once the aggregation of sufficient structured data about buildings throughout their life cycle has taken place, there will be amazing

applications. This data can be organized and used as benchmarking and knowledge base data. For instance, the ability to "load" a BIM model and a construction schedule, analyze potential construction delays based on a building system, and determine the average durations of past projects will ultimately help optimize design.

Predictive Maintenance

The use of BIM data to drive predictive maintenance on a building is still in its early stages but is, in fact, growing. Analyzing the BIM data across a portfolio of buildings while being able to determine maintenance cycles on major and minor building systems allows for fewer unplanned outages as well as greater precision in operational budgeting. Additionally, being able to benchmark against similar buildings (and portfolios of buildings) will assist in assessing comparative performance.

Constructability Analysis

Constructability analysis is an area that is also growing rapidly. The concept of simulating the construction process and predicting outcomes has a tremendous benefit to owners. It has become the next generation of a traditional plan review service. While a plan review service can create value, because it functions as a peer review, it is indeed quite limiting. A BIM-based constructability analysis provides the base benefit of a traditional plan review in addition to the by-products of BIM-based simulation. The ability to aggregate constructability data and analyze it against actual outcomes allows owners to understand the quality of the work product from their design teams and, more specifically, how it drives construction delays and budget overruns. An example of BIM analytics and the extension of these analytics to the owner's benefit is the iBIM Constructability Index (CI). Our team at ARC developed this tool to assist owners in scoring the constructability of a building project.

The iBIM CI is a proprietary benchmarking system. The system is used to provide a project-specific risk rating that can be used to mitigate construction risk. Based on the quantity and severity of the discrepancies, the CI can rate each discipline performance and then combine the scores for a total project score. On a scale of 0 to 100 percent, 0 represents the worst outcomes and 100 percent represents

the best outcomes. Listed below is each discipline with its corresponding CI score and an overall project score.

These efforts result in significant payback to the proposed project; this process has provided cost reductions of between 5 and 20 percent, benefit/cost ratios of up to 10:1, and large schedule reductions. The intangible benefits are as important as the quantitative benefits and must be recognized accordingly. These include more accurate contract documents by reducing requests for information (RFIs) and change orders, reduced schedule impact, increased productivity, and improvement in the sequence of construction.

Product Manufacturer Analysis

A typical building consists mostly of manufactured products. The building product manufacturers (BPMs) are vital members of the construction ecosystem. Although they have already become involved with the BIM process, it is still early for many of these BPMs. Some of these provide product information models (PIMs) for use in BIM software, which centers on the concept that, as virtual buildings are created, virtual products will need to be installed in the virtual buildings. These PIMs need to resemble the actual product as closely as possible. Like the rest of the industry, BPMs have suffered a few "false starts" in providing this information. These challenges are caused by the BPMs' mind-set of treating this information like CAD details, without truly understanding the BIM process. BIM drives a need to understand the construction *process* and the product, not just the construction *content* and the product. There have been encouraging signs from some BPMs that are making significant commitments to be part of the ecosystem rather than existing as mere suppliers to the ecosystem.

The BPM community is now adapting many of its configuration tools to work within BIM software or be compatible with BIM file formats. Many BPM companies have added BIM capability to their support staff so that they can truly collaborate on projects. Connectivity to product availability and pricing configuration is not currently a focus but will be the next step in BIM adoption. (See Figure 1.1.)

Building Management Systems

Integration of building management systems (also called building automation systems) and BIM is a growing trend. The concept of
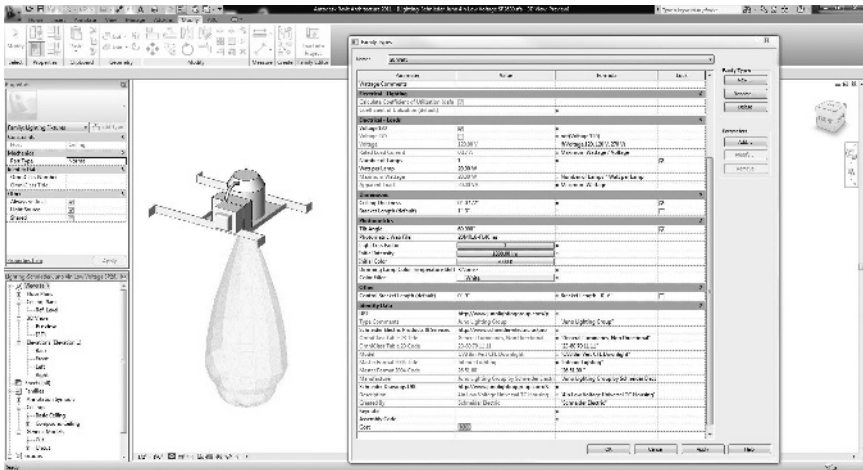
Figure 1.1 Installed information of a system.

intelligent buildings has been around for several decades. The challenge has generally been the ability to have detailed information about the building, its systems and intelligence. Now that many new buildings will have detailed building information from the BIM, integrating this data into intelligent building management systems becomes seamless. These systems are a combination of software and hardware. The software is used to create a command and control environment to manage almost all aspects of a building. The hardware consists of supporting systems for the software but more uniquely the digital control systems that control building systems. Much like a standard office computer network is a series of connected systems, a building management system is a network of connected building systems. These building systems include occupancy; security; heating, ventilating, and air conditioning (HVAC); lighting; hot/cold water systems; fire protection and alarms; window shades; room automation (video projectors, drop-down screens, etc.); and communication systems. These systems can be very complex and often include a series of vendors for each specialized system. The ability to use BIM to design and systematically implement and integrate these systems is critical. The other benefit of building management systems is that the building begins to behave much like a typical computer system. This gives an owner the ability to review the log history and generate analytics regarding building performance. This data can be used for future building modifications as well as knowledge for any new facilities

that are being designed. These systems can also execute standard routines for a building. These routines would automate a set of events based on a use case. For example, a morning start-up routine for a building would be a combination of security events, HVAC events, and alarm systems. The system would unlock the external doors and restricted corridors, turn on the air conditioning, and switch alarms to passive mode in restricted areas. While this would be a typical recurring event, unplanned events can be developed for automated routines. These could include anything from a water leak to a terrorist threat.

Building management systems are becoming highly sophisticated neurosystems for the building. The costs associated with operating a building combined with the green initiatives that many companies are driving make building management systems a must. The technology is becoming more widely available and with better capability for integration. Many building owners may have a system for their core buildings and are now having to integrate into the tenant-specific system. More important, these systems are now more interconnected with the user community of a building. Consider the following example. A user swipes his or her access card to enter a building after hours. Upon swiping the card, the building knows that the user is an executive who occupies a certain office in the building. The lighting system turns on lights for this executive only in the path to his or her office. The office and adjacent break room lighting and climate controls are engaged. The executive completes his or her work. Upon exiting the building, the executive swipes his or her card, and the building knows to turn off the respective systems. This use case is readily available today and is being used. This innovation and integration has attracted many information technology (IT) systems companies to this space, including Cisco and IBM. It has also begun to blur the responsibilities of the facility manager and IT manager. Buildings are starting to behave much more like an IT system than a building system.

Facility Management Systems

Facility management (FM) systems are adopting the ability to integrate into BIM technology as well. This will allow an owner to click on a system in the BIM and understand such items as install date,

who installed it, maintenance performed, and warranty information. This provides an owner with rich information about its building assets. Additionally, an owner is able to communicate with maintenance companies, contractors, and so on with more information during discovery, without having to pay for a subcontractor to determine existing conditions. This will ultimately drive more competitive behavior while at the same time lowering costs.

To discuss how BIM pertains to facility management, let's first discuss typical FM core processes and how they can benefit from the use of technology. These core processes are facility maintenance, asset management, space management, move management, and strategic planning.

Facility Maintenance

Facility maintenance refers to the upkeep, support, and maintenance of building equipment. Facility managers typically keep an inventory and detailed history of equipment and related maintenance requirements, enabling their organizations to extend the life of valuable equipment. Facility managers need to coordinate supervisors, technicians, workshops, and outside vendors to complete facility maintenance tasks. They must also record contract expirations in a database in order to reference or define automated alerts required for preventive maintenance.

From a process perspective, facility managers should incorporate automation for the tracking and reporting of critical data associated with service requests, such as repair costs, response time, and work history. Efficient facility managers use self-service request forms and work order status views for internal customers, send e-mail reminders to themselves and to their vendors for preventive maintenance tasks, and create maintenance tickets automatically for scheduled maintenance jobs. Additionally, the facility manager will route work orders to internal staff and vendors and run reports on various vendors and equipment to analyze costs.

Asset Management

Asset management describes the process of tracking multiple classes of assets—office equipment, furniture, computers, life safety systems, building systems, lab equipment, corporate artwork, and so on.

Assets can be linked within a BIM model to show location, owner-ship, and access to product information—which can greatly improve efficiencies in maintenance and personnel move processes. An effec-tive facility manager will track and locate in a BIM model or on floor plans such corporate assets and define processes for tracking such things as costs, disposition, availability, and assignment.

Space Management

Designed to give facility professionals, departmental liaisons, and executive management complete visibility into workspace occupancy, space management describes the process of managing real-time infor-mation related to the use of space in an organization. A facility man-ager needs to plan, track, and report employee moves, in addition to tracking the notification process. Space management processes allow the facility manager to effectively plan and manage new employee installations as well as move team members and outsourced vendors to new facility locations.

Move Management

This aspect describes the processes that allow the facility manager to plan, track, and report employee moves. Facility managers need to be able to effortlessly coordinate move liaisons as well as move team mem-bers and outsourced vendors. For example, move management can be used to automate existing employees who need to submit move requests to a manager, who will then notify the facility manager for coordination, approval, scheduling, and completion of workspace installation.

Strategic Planning

Strategic planning allows for multiple "what-if" scenarios and visual depictions of an organization's current and future space and occu-pancy rate, using forecasting tools to align a company's space portfo-lio with its business requirements.

Facility managers will need to maintain an accurate inventory of space, such as locations, room numbers, space types, areas, and capacities. The goal of the strategic planning process is to give facility

professionals, departmental liaisons, and executive management complete visibility into space and occupancy. The facility manager should seek to centralize space and occupancy information across all locations, provide visibility to management and internal customers, and empower departmental liaisons to manage and maintain space and occupancy information. The facility manager will also improve occupancy rates and space utilization with detailed space inventories, accurate occupancy data, and facility benchmarks.

Software Tools

Many vendors provide software tools that use a core component along with additional modular applications, each focused on the different aspects or processes associated with facility management. These systems should act as a central FM database, which can be accessed and utilized throughout a building's life cycle.

Typically, these programs work as integrated packages of powerful Web-based workplace management products that allow an organization to share information and manage processes that impact the entire facility. Such FM software tools ideally can be accessed by all employees using standard Web browsers, and they feature intuitive interfaces to provide access to key facility information such as floor plans, reports, employee information, and critical documents. These software packages are typically referred to as computer-aided facility management (CAFM) and computerized maintenance management system (CMMS).

CAFM software automates many of the typical functions of facility management. The International Facility Management Association (IFMA) classifies facility management responsibilities into several major functional areas:

- Long-range and annual facility planning
- Facility financial forecasting
- Real estate acquisition and/or disposal
- Work specifications, installation, and space management
- Architectural and engineering planning and design
- New construction and/or renovation
- Maintenance and operations management
- Telecommunications integration, security, and general administrative services

Asset Management Software

Effective asset management software will use graphical queries to search for and visually display assets on floor plans. The system will allow the facility manager to define the method by which to track asset depreciation for financial reporting and compliance, as well as ownership and product information such as serial numbers and installation dates. Asset management systems can also be integrated with other systems, such as bar codes or enterprise resource planning (ERP) systems, making asset tracking efforts more robust.

Space Management Software

Facility managers must be empowered to plan visitor installations on digital floor plans or BIM models. Visitors need to be able to submit their requests to the facility manager via electronic forms, which are then automatically routed through the approval process. Additionally, the AutoCAD integration component of many space management software systems enables users to link a Revit model and AutoCAD drawings to their FM databases. Through menu selection, this link allows for a bidirectional update of key information such as room IDs, personal room assignments, departments, area measurements, and other corresponding information that the organization may require.

The platform also needs to be able to coordinate move details efficiently for people, assets, and infrastructure components. An effective software solution will manage space requests, so that they can be forwarded to the facility manager for coordination, approval, scheduling, and completion. The platform should also allow employees to have the ability to report on every stage of the process.

Move Management Software

Move management software can enable internal customers to submit their own move requests via Web-based forms, which are automatically routed through the approval process. The move requests can be forwarded to the facility manager for coordination, approval, scheduling, and completion, and employees have the ability to report on every stage of the process. Effective software platforms contain the ability to coordinate move details quickly for people, assets, and infrastructure components.

Strategic Planning Software

The facility manager will typically gather and forecast space needs by growth criteria, such as head count, staff detail, area, and percentage growth, before utilizing a platform to assign an employee to a new space. A facility manager will also use a system that considers adjacency, stacking, and other factors that will determine the new employee's location. The platform will need to be able to run reports on space and occupancy projections as well as be able to automate notification to workspace vendors and laborers.

Additionally, the modern facility manager will need to link facility information to detailed spatial information in Revit and use a Web browser to navigate and visualize real-time facility data on the floor plans. This platform should also allow the user to compare utilization data with portfolio performance as well as link space to groups and cost centers to track use of space by department and support space chargeback policies.

Many strategic space planning platforms will also contain an integration component that enables an organization's users to link a Revit model and AutoCAD drawings to the building databases. This link should allow for a bidirectional update of key information such as room IDs, personal room assignments, departments, area measurements, and other corresponding information that the organization requires.

CMMS is sometimes referred to as enterprise asset management because it is focused on managing facilities as an asset, including maintenance. Maintaining an asset ensures the long-term value of the asset, but tracking all activities associated with the asset provides not only proof but also data for future maintenance costs. Many owners retain more detailed information about their fleet of vehicles than their $20 million building asset. This is a challenge because of the vast amount of data to be tracked in a building. BIM and CMMS systems assist owners in overcoming this challenge.

Facility Maintenance Software

Facility maintenance software should enable the facility manager to keep an inventory and detailed history of building equipment and related maintenance requirements. Many platforms allow the team to receive e-mail reminders for routine tasks (such as six-month

checkups on air-conditioning units and copiers) and automatically create a maintenance ticket in the system. Generally, facility maintenance platforms will allow the facility manager to maintain an inventory of building equipment with maintenance and cost history as well as automate preventive maintenance scheduling and work orders. FM platforms also associate critical data with self-service requests, such as repair costs, response time, and work history to be tracked, reported, and monitored.

In summary, using FM software tools allows the facility manager to effectively plan new and existing employee moves, manage visitor installations, reconfigure rooms and workspaces, track assets, and manage the entire facility. The facility manager should also seek to improve internal customer service, so the software used should allow the manager to access property information with a map-based interface, run live reports, view floor plans, search archived drawings and critical documents, and share facility data with management, partners, and internal customers within a corporate intranet. The combination of software accessibility via a Web browser interface with the intuitive interface of BIM will provide data to the entire owner enterprise and not just a few that manage the software. This will not only create value to the owner/user community but also will decentralize the collection of data. The decentralization of data creates an environment where data is kept more current and where it becomes more useful and reliable to the user community.

> Organizations would never try to build a new building without detailed and correct drawings, yet they rebuild facilities piece by piece every three to six years without correct drawings because they have never provided for staff to update the original drawings properly. Once BIM becomes standard, the problem will be lessened to the degree that we are willing to constantly keep our drawings updated. For those of us who have a large inventory of older buildings with building drawings of uncertain validity, it is worthwhile to systematically have those buildings surveyed, their systems categorized and their drawings brought up-to-date. BIM should be the standard for all new construction and for major renovations. The ability to conduct BIM and to receive the data may well determine which consultants we use and which building automation system we move forward with.[1]

Building Owner Objectives

BIM is a digital database of physical and functional characteristics that also contains information about a building that can be viewed in more than three dimensions. It enables an organization to virtually build the building as it would be constructed on-site before the actual construction has started. This helps to eliminate many of the inefficiencies of the construction process. The information updated in the BIM at each phase by the team members can be transferred to the next phase without any loss or duplication of information. The model can be accessed by any stakeholder for entering, updating, or extracting information at any point during construction. Upon completion, the data-rich model can be delivered to the owner or the facility manager. This model can then be used for operating the building throughout its entire life cycle. In summary, this is the vision of BIM—but currently there are many factors that do not make this feasible.

BIM has proven to have benefits for every key player in the construction process—from design to construction to facility management. A building owner holds special incentives to implement BIM, not just for the construction of the building but for the maintenance as well. Owners like the General Services Administration (GSA) and the U.S. Army Corps of Engineers (USACE) have taken extreme steps regarding mandating the use of BIM. They believe that BIM adoption should not be driven by cost savings alone but for its other benefits such as the ability to explore different engineering systems, perform energy analysis for Leadership in Energy and Environmental Design (LEED) certification, generate specifications automatically, and eventually eliminate the use of paper and paper-based processes. BIM can be used for creating as-built documentation for existing buildings, space reporting, and spatial and tenant management as well as for evaluating how well a proposed design meets the program requirements. BIM-enabled project owners gain a much higher confidence level about the design and overall construction of their buildings. BIM reduces overall project delivery time in the design phase while reducing the contractor's uncertainty. Consequently, this leads to a more accurate cost picture with more consistent bids.

BIM has dramatically changed the construction process. Construction has been known for its notorious relations involving the contracts among team members. According to the Construction

Users Roundtable (CURT) publication WP1202, 30 percent of the cost of construction is wasted in the field due to coordination errors, wasted material, labor inefficiencies, and other problems that arise during the traditional course of construction. Even though owners may know many of the facts and "numbers," they still accept the price of waste as a part of the overall construction cost. They then build this cost into their estimate, budget, fee, and contingency— which is all ultimately paid by the owner. One of the major causes of these inefficiencies is the horizontal and fragmented supply chain arrangement in the AEC industry, where information is passed from one party to the next in a linear fashion. Each party has its own vested misaligned interest and goals toward the project. In order for owners to realize their own objectives, they should modify this arrangement by engaging the entire team to work "outside of the norm" and under one umbrella, adopting new, more efficient methods of project delivery.

In order to improve efficiency in project delivery, the entire process must achieve a higher level of coordination. This can be achieved through better integration of information and improving process optimization. BIM is a tool that promotes much more detailed collaboration from early on in the life of the project. Many owners require an integrated project delivery (IPD) approach in their projects, which is a reinitialized method of project partnering that uses the talent, experience, and input of all the team members starting at the beginning of the project. However, owners implementing IPD must think outside of the box to leverage BIM for its maximum capability. In an IPD arrangement, all of the project members have one common goal—the success of the project. In theory, this method increases the value for the owner by reducing waste and optimizing efficiency. The IPD process is usually applied throughout the life cycle of the project, which starts with design and fabrication and then continues through the completion of construction. By following this process, an owner reaps the benefits of engaging the construction team early in the design stage for their vital contribution on constructability analysis and value engineering. Owners should also realize that, in an IPD arrangement, the benefit is to the entire team, and there is both mutual risk and reward. In many ways, IPD is a more creative way of subordinating a portion of the risk while also benefiting from a part of the reward. BIM creates a platform that makes it possible to bring in all of the team members at an early stage so as to further increase

each other's value and effectiveness. A contractor can start working on constructability analysis of the design even when the design is in an early and incomplete state.

BIM also creates an effective lean process for construction. Lean refers to a process or philosophy of reducing waste (time, material, and labor) and increasing value. The lean process has been applied to manufacturing and is now making its way into construction. The fundamental focus of lean is the concept that *anything* that does not create value to the consumer is considered waste. Value is not a subjective attribute but rather a financially motivated metric. Owners must understand their value drivers before undertaking any type of construction project. Fundamentally, value drivers are different for each owner. Typically, the waste embedded in the process includes change orders, poor information flow, rework, and so on. BIM, when coupled with lean, creates a tool for reducing waste and improving the overall process of project delivery. It achieves significant improvement by simulating the building process in a virtual environment and provides a better analysis with significant documentation. Utilizing BIM along with lean reduces the overall cost of the project by identifying issues at a time when they are still inexpensive to fix or at a time when the value to the owner can be determined. BIM also provides owners with vital decision support data, so that they can better understand the true value of a design change prior to construction. The cost of any change in the construction is inversely proportional to the point in time at which it occurs. In current practice, it is not uncommon to find most of the changes on-site during construction at a point at which the cost of making these changes is not manageable or possibly even feasible for the owner.

There is a general misconception in the construction industry that IPD is required for BIM to be effective. Another is that the owner and the AEC community are working as a team. In the majority of IPD projects (or attempts), the alignments of cost, benefit, and risk have not been shared. In some ways, the classic situation of "quality, schedule, and cost: pick any two" is prevalent. Upon completion of an IPD project, most owners will agree that IPD allowed them to execute the project, beat the schedule, and ultimately deliver a quality product. However, price was sacrificed in the process. Technology should allow us to improve quality, schedule, *and* cost at the same time. Typically, the only sacrifice that is made is in the area of human interaction. With this in mind, it is essentially the owner and their

vendors (the AEC community) who focus on delivering on price, quality, and schedule by leveraging technology.

> It has gone so far that many teams in today's companies are not true teams at all; they are not simply set up to work together effectively organizationally, structurally, or motivationally. Branding "Teams" to a project is simply placing vague labels placed on random groupings, or even the entire organization as a whole. These labels accomplish nothing. Frankly, someone has told leadership that they should have teams, and so they have them. Make no mistake, employees are not fooled. They continue to operate as groups or departments of people that simply have the blanket of "team" thrown upon them. Look further and you'll find a group of individuals largely fending for themselves.[2]

User Experience

"User experience" is a term that has historically been reserved for the software design community. While most believe that user experience is explicit to how a user feels when using software, this is a subjective view. In fact, user experience is scientific, and in most cases, the user community is fairly predictable. When the World Wide Web was in early adoption, Web sites were designed in many different ways. Over time, the layout of a Web site came to be quite predictive. When users on the Web are surveyed to provide site usability, the outcomes are typically the same. This recurring comfort that is developed then becomes the standard. In many ways, the user experience for an owner has not changed much over the years. The deliverables are the same, and the interactions with both the design and build community have been consistent. Technology has only shaped the efficiency and automation of manual efforts but has not made a noticeable change to the core process.

The term is applicable to BIM from many different aspects. BIM should be driving a new user experience for the owner. The owner, in turn, should be changing the user experience for its user community. Unfortunately, design review meetings have continued to be the same. The designer meets with the owner to review plans, renderings, and the like and to receive feedback. With the advent of BIM, the designer

may arrive with a 3-D model, spin it around a bit, and, after an uproar of applause, move through the meeting. In this case, BIM has been leveraged for the visualization aspect only, but the process has remained the same. Buildings are highly complex, and BIM has helped in creating an environment by which an individual's inability to read construction drawings has not limited his or her ability to provide input to the design process. An owner representative's job is to drive the process to the benefit of all of the stakeholders. This includes the building users, maintenance workers, and so on. Between the advent of distributed computing and BIM, the ability to involve the stakeholders in the design process is an exciting opportunity. This can be accomplished by a method known as crowdsourcing.

Crowdsourcing is the process by which tasks normally performed by employees are outsourced to large groups of users or consumers. Crowdsourcing has become a standard procedure for Web application deployment. Common are beta programs that many companies like Google deploy, where users can utilize the technology in return for providing feedback. Private crowdsourcing is being used to solve complex problems in health sciences by posting a product development challenge to a group and offering a fee to the person who solves the

Figure 1.2 Talent in the cloud. *Courtesy Buffi Aguero*

problem. In some cases, these fees are in the hundreds of thousands of dollars. The leverage of knowledge from many users provides the benefit of mass knowledge as well as specialized knowledge.

For example, a hospital has many constituents in a new building program. In the past, an owner community would be formed to provide and represent the needs of the constituent stakeholders. Using BIM and other collaborative technologies, a hospital would set up a Web portal that included the BIM model. When executing the utilization viewer technologies, a link would be sent to the user community. These users, such as doctors, nurses, financial analysts, medical equipment suppliers, patients, and maintenance workers, would view and walk through the BIM in order to provide structured feedback. This feedback might not exclusively pertain to space use and needs but might even include the use of specific products and equipment. It would create an overall user experience for all of the hospital stakeholders. For instance, if the maintenance team could see the flooring products that are being used, they could provide feedback that the product being considered is high maintenance and would require outside contracting maintenance. Other examples would include a product manufacturer suggesting that there is a newer product that is more efficient from an energy or space requirement. Doctors and nurses might communicate that they no longer use the examination room furniture because they are using electronic medical records on their tablet devices. Crowdsourcing is used to leverage the knowledge of the masses. Although this could have been done in the past with 2-D drawings, the community would have to be limited to users who could read construction drawings. (See Figure 1.2.)

Similarly, the user experience for an owner and its design/construction team is changing. The owner is no longer a passive team member with great influence but rather an active team leader that drives the team to success. This is where there is great disagreement surrounding the applicability of BIM to small projects—the argument being that it is not cost effective or even needed. The contrary is true—large projects are managed by experienced owners and team members, and BIM is used to manage the complexities. The owner is very active in the project process, or at least should be. In smaller projects, an owner's input is critical to understanding the risks and opportunities of the project success. BIM on a small project empowers owners that build infrequently to be actively involved through knowledge without being intimidated by their lack

of experience. Additionally, BIM provides transparency around their decision-making process based on facts and not on the opinions of their vendors.

Communication

The need for communication is basic to any organization. All owners will say that they wish their vendors would communicate more. Quantity is not really the issue; rather, it is the quality and relevance of the communication that is important. Critical thought in e-mail has been replaced by stream of consciousness. Automated systems such as Web collaboration have added to the volume. While technology has increased the ability to communicate, it does not necessarily mean that the quality of communication has improved. With the advent of e-mail, the ability to send an e-mail to everyone on a project has crammed our in-boxes with information at a pace that has become unmanageable. BIM has the potential to bring a new level of quality communication to an owner. It also has the potential, due to the volume of data generated, to create increased volumes without increased quality.

Visualization has been a key feature in BIM that has been the basis of much excitement in the industry. Within some organizations, BIM is viewed purely as a visualization tool and is sometimes referred to as 3-D software. Early adoption of BIM was mostly used for marketing purposes. While BIM is much more than a visualization tool, it does not mean that the visualization aspect is not highly beneficial. It increases the quality of communication between owners and the design and construction vendors. Not all owners have the spatial aptitude to read plans and visualize spaces. The typical renderings that are used for design decisions with owners are helpful but lack detail to make specific decisions. The visualization capability also engages additional stakeholders within an owner's organization.

As BIM continues to evolve, owners will benefit from additional communication not just through visualization but also through reporting. The ability to extract data from the BIM database will give owners specific information about their buildings.

The tools available to foster communication are typically referred to as collaboration tools. Collaboration can have a broad definition, and the tools associated with collaboration can be as simple as

A TALE FROM THE TRENCHES

An owner received a BIM from his contractor, not as part of a requirement but because the contractor used BIM as part of its construction process. The contractor used BIM for coordination and saw great benefit in laying out mechanical rooms that had limited space. The owner walked through the model and was very impressed with the layout. The owner then had a maintenance manager meet with him to look at the model. When they walked into the mechanical room, the owner demonstrated how efficiently the contractor was able to fit equipment into the space. The maintenance manager walked through the room in the BIM and pointed out that while the equipment laid out well, performing maintenance would require a gymnast. The maintenance manager provided input that would make performing maintenance more accessible.

sending e-mail or posting to a File Transfer Protocol (FTP) site. It can also be as complex as product life cycle management (PLCM) systems. There are myriad Web collaboration tools on the market, such as SharePoint, PlanWell Collaborate, Buzzsaw, Basecamp, Zoho, ProjectWise, Horizontal, Tekla, Solibri, to name a few. But none of them supports BIM files in a way that is independent of BIM authoring tools and incorporating authoritative workflow to make changes to the model. These systems will start to become prevalent. The focus of sharing a model is the mildest form of collaboration, but until every stakeholder in the project can provide feedback within an authoritative framework, there will be challenges. The word "authoritative" is important as it relates to professional liability. If the twenty-five-year-old CAD (no BIM) operator is making a change in a BIM model on behalf of the structural engineer of record, it requires authoritative approval. The real-time trailer meetings for BIM coordination can be beneficial as long as authoritative members are present to make real-time decisions and approvals. This is rarely the case.

Procurement

Any BIM, if loaded with all possible building information, will have all of the specifications and quantities built within the model. Therefore, the architects can "take off" the exact quantities for estimating the pre-bid budget. With a BIM, even a general contractor

can take off quantities to match and confirm its own quantities. Each object in the model can have a price associated with it, making it easier to generate a bill of materials and product cost estimates. For example, a hotel owner can have 5,000 rooms that have the exact same requirements for carpets or tiles. This can be used for cost estimates up front while tracking renovation and maintenance procedures with a greater level of accuracy.

Using BIM to determine the gross quantity of commodity materials (steel, copper, etc.) will continue to be important. With natural resources and commodities being subject to global demands and market volatility, the ability to develop commodity hedging practices is becoming important. To use a large-scale example, the airline industry depends on fuel hedging in order to run a predictable enterprise. On a large project, from planning to buyout, the time frame could easily be over a year. The ability to determine commodity quantities could hedge against increases of 10 percent or more. In a thriving economy, the inflationary pressures are passed on to the consumer so there is less sensitivity. In our current economy, projects will be at risk due to increases in the price of commodities. These price increases will not only affect raw materials but also the components that depend on these materials as well as fuel surcharges. Breaking down a building into a portfolio of commodities and building a hedging strategy may become the new norm.

This ability to break down a building into a bill of materials has many possibilities. Specifically in health care, group purchasing organizations (GPOs) have been able to create leverage through high purchasing volumes to drive health supply costs down for many hospital groups. While some aspects of new construction have been applied, such as furniture and equipment, there have been difficulties in leveraging spend in the more rudimentary building materials. This has been a challenge due to the lack of historical data and early data to predict material needs. The concept of the GPO would have great applicability to other owners as well as owner groups that choose to leverage their buying power. Many general contractors have the ability to leverage their buying power of materials but rarely pass these savings on to the owner. It is not in the general contractor's interest to pass these savings on to the owner and, in fact, would be detrimental to the contractor's project profitability.

In an era of just-in-time inventories and flexibility in both the supply chain and logistics, BIM data can be used to reduce materials

management on the job site. This will reduce the opportunity for theft and damage and also streamline site logistics. BIM is used for site logistics quite frequently on difficult job sites but is more recently being utilized on more common projects that may lack site logistics challenges.

Design Guidelines

For a very aesthetically oriented building, BIM provides architects with infinite freedom to showcase their creativity. BIM also provides the ability to develop the wildest design concepts within the constructability analysis of their design. The designer can utilize the volumetric and system assembly data to analyze the building concept. BIM also increases the accuracy of the design and streamlines the coordination of contract documents. BIM allows designing and documentation concurrently in an integrated approach. If at any point the owner decides to modify the exterior of the building by switching to a different material, the architect only has to change the design and material in the BIM model. The material takeoffs, finish schedule, and specifications are updated automatically with limited additional effort. BIM does not only save the architect time, but it can also help prevent delays in the project. Because of the parametric nature of BIM, the designer and the owner have the capability to experiment with materials, space, and design quality so as to meet an owner's budget.

The BIM model provides a visual aid that can dramatically improve communication and understanding of the proposed building and its integrated systems. The accuracy in the coordinated construction documents allows the general contractor to provide the owner with a very accurate bid. Since the construction documents are more accurately prepared with BIM and have fewer mistakes or missing information, owners feel more relieved from the liability of the Spearin Doctrine (for any of the architect's mistakes). The Spearin Doctrine is a legal standard that is in effect when a contractor follows the contract documents (plans and specifications) furnished by the owner. These CDs tend to have a great number of errors and omissions for which the contractor cannot be held liable to the owner; thus, the owner is affected by any of the losses or damages resulting from the CDs.

With the advent of new software, a BIM model can be checked for the constructability of design and validation of the model to produce CDs by using software-based "model checkers." These model-checking software packages can be used to validate design guidelines and codes. For example, the Solibri model checker has several extensions to check codes for Americans with Disabilities Act (ADA) compliance and green building certification, as well as GSA regulations. It assists with validating code compliance by automatically checking the building codes. This assists owners in resolving most, if not all, of these code compliance issues before they are discovered on-site and pointed out by a contractor. Additionally, rule sets can be custom developed by an owner for any specific requirements that it may have based on its individual experience. See Figure 1.3 for an example of a model checker.

The reality is that, in most cases, architects are using BIM software simply as a 3-D drafting tool. They have invested in BIM technology for their own benefit. The software creates internal efficiency, better-quality deliverables, and an engaged customer experience. While this is a vast improvement in the overall construction process, the benefit to the owner is nonexistent. Furthermore, there should not be a benefit, considering the architect has invested in BIM in order to improve its own internal processes, but the owner is still receiving the same contracted deliverable. Architecture firms using BIM are reducing their internal costs to produce and are benefiting by
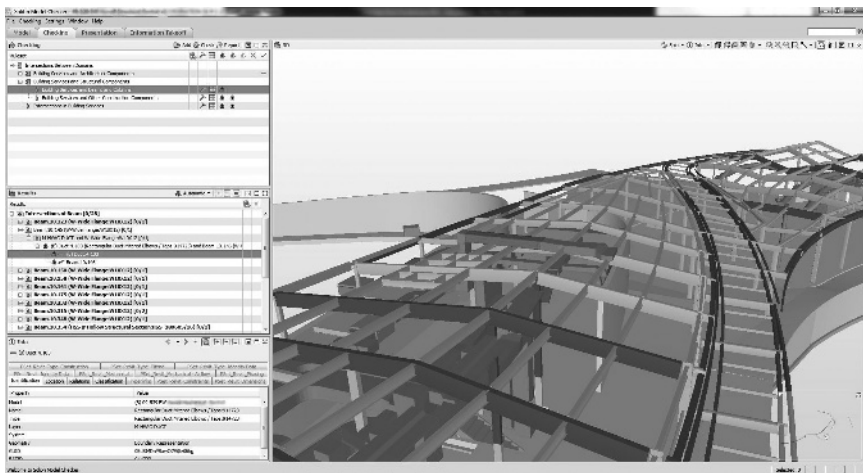

Figure 1.3 Example of a model-checking routine.

better project margins. The challenge to owners is that they are paying for a deliverable (construction documents) and are not involved in the methods by which the architect produces the CDs. It is generally unreasonable for owners to ask for a deliverable for which they are not paying. In a lump-sum contract, an architect benefits from process efficiency, and an owner benefits from mitigating design fee overages. The focus on design fees has always been perplexing, since they are a relatively small portion of the construction budget. BIM is a great opportunity for an architect to have value-based fees and improved margins. I have been involved with architects that have attempted to charge owners for the use of BIM for the same deliverable. It is simply not logical for an owner to pay more for the same deliverable, when technology makes the process more efficient. It is also unreasonable for an owner to expect that a BIM created by the architect *for the architect* has any value to the owner. An owner should develop a requirements specification for the BIM to meet its needs and be willing to pay the architect for the deliverable. In turn, the architect should be able to warrant that the BIM meets the owner's specifications.

Construction Process and Costs

In the traditional construction process, a large portion of the planning and coordination on the project occurred primarily in the architects' and engineers' minds and was not supported by technology. Hence, their decisions were mostly based on human interpretations of information generated by architects and engineers from many disciplines. The 2-D coordination enabled the coordination in just two dimensions and did not validate the space in any other dimension (see Figure 1.4). This resulted in inconsistent and repeatable outcomes from meeting to meeting and project to project.

BIM provides a much greater level of accuracy, which benefits all of the trades and builders involved in the coordination process. BIM also helps to avoid the "fix it in the field" approach. Trade coordination can proceed once the design is complete and is ready to be fabricated. The fabrication of the building systems is far more accurate after the coordination process. The discoveries made during the trade coordination process can save owners a huge amount of money and time. These savings mainly come from mitigating change
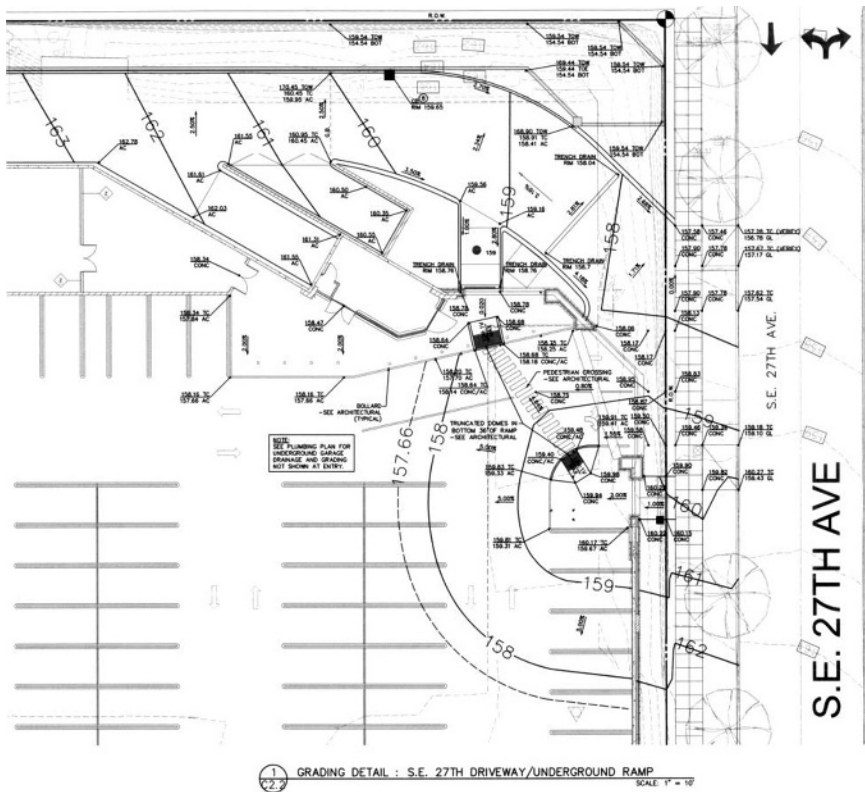
Figure 1.4 Image of 2-D coordination.

orders. Usually, the collisions found through BIM trade coordina-
tion are found on-site during installation, after all the parts have
been fabricated. Changes to the construction at this point lead to
very expensive change orders, which can be mitigated if the trade
coordination process is adopted up front. While many owners are not
involved in this process (nor should they be), they also believe that
this inefficiency does not cost them. The reality is that these ineffi-
ciencies drive costs that are ultimately borne by the owner. An owner
may not receive a separate invoice for construction inefficiencies, but
it is built into the price. Otherwise, there would not be many contrac-
tors in business.

Often the most effective ways to understand, evaluate, and make
a decision at each critical point in the construction of a project can
be done by using BIM tools. This has been proven to streamline the
decision-making process and has provided the opportunity to quickly

evaluate and analyze the "what-if" scenarios. A contractor that is effectively using BIM receives great benefit for mitigating risk. In some cases, the savings are passed on to the owner, but in most cases, it's the contractor that benefits.

In construction, time is money. While every owner is seeking a reduction in costs, the schedule is equally important and cannot be overlooked. Owners also benefit greatly from the fourth dimension of a BIM model. A four-dimensional (4-D) enhanced model enables a diverse team of project participants to evaluate and comment on the project scope and corresponding schedules in a very proactive and timely manner (see Figure 1.5). 4-D enables the exploration and improvement of the project execution strategy, facilitates improvements in constructability with corresponding gains in on-site productivity, and makes possible the rapid identification and resolution of time-space conflicts. Different objects within BIM are linked to various scheduling software such as Primavera or Microsoft Project, which result in 4-D construction simulations. By visualizing different scenarios, the entire team can clearly understand construction-related safety, logistics, planning, and sequencing issues. When these issues are identified, it becomes easier to identify the most effective way to build the project. 4-D BIM models have proven particularly helpful in projects that involve many stakeholders, such as projects undergoing renovation during operation,

Figure 1.5 4-D enhanced model.

or projects with tight, urban site conditions. The procurement of preassembled materials can be coordinated within the BIM model using its third and fourth dimensions, avoiding any delay or duplication. This just-in-time delivery not only makes the process very efficient but also saves money on material storage, while also avoiding delays in construction due to uncoordinated procurement delay. For an owner, the use of 4-D techniques creates better transparency into the scheduling process. It is also an opportunity for an experienced owner to provide insight into reducing logistics expenses in a planned environment rather than an ad hoc environment.

As discussed previously, a data-rich BIM contains all of the potential building information, including the specifications and quantities contained within the model, that allow the architect to run takeoffs and opt for the exact quantities used in estimating the pre-bid budget. In order for the BIM to have useful data, the model must be created with the data embedded into the model. A general contractor can also take off quantities to match and confirm his own quantities. Each object in the model can have a price associated with it, making it easier to generate a bill of materials and product cost estimates. If performed correctly, an owner can use BIM prior to hiring a contractor and receive preliminary pricing from manufacturers' representatives. If owners understand the specifics of spend in their buildings, they can apply lean principles to ensure that their spend is commensurate with their value drivers. By leveraging the knowledge base of the manufacturer community, owners can seek alternatives that align with their value drivers.

Sustainability

If an owner desires a green building, energy analysis is one of the primary benefits of using BIM. There are numerous ways that utilizing BIM results in more efficient buildings. The software can analyze and help owners to predict energy cost during the early design phase, which helps architects to understand how their design would impact energy consumption and costs during the building's life cycle. Facility managers can also use this data for benchmarking a building's energy consumption. This information can be helpful to owners with the same usage type and also in the application and maintaining of certification for LEED-EB operations and maintenance (O&M).

Buildings in the United States are responsible for almost half of all annual greenhouse gas emissions, and they consume over three-fourths of the electricity generated by power plants. Globally, electricity used by commercial buildings alone has almost tripled since 1980 and is projected to rise by another 50 percent by 2030. The incremental growth in the usage of water, electricity, raw materials, and natural resources, along with the generation of pollution and waste, has left us with no option except for government enforcement of directives for building owners. Several states have already enacted a wide range of regulations on green building standards and their emendation. For example, the Green Building Act in New York City requires that new municipal buildings, along with additions and renovations of existing buildings, meet green building standards. The California Code of Regulations also sets minimum energy efficiency standards for all new homes, additions to homes, alterations of existing homes, and most commercial buildings. The goal of these directives is to increase building performance by minimizing energy and water consumption, improving air quality, and creating smaller overall footprints. The EU Energy Performance of Buildings Directive focuses on cutting energy use by 20 percent by 2020. The Energy Independence and Security Act (EISA) requires a steep reduction in fossil fuel energy use and encourages the use of solar energy. With an increase in these types of mandates, building owners are being forced to look at their building performance index and reassess the building design. Building owners are now looking back and assessing their existing building stock while working to improve their building performance so as to meet the higher standards. Along with these mandates, the government is also providing certain tax incentives to lure owners into compliance. Figure 1.6 shows a model being analyzed to meet green building objectives.

With the use of BIM, an existing building owner can make an intelligent and informed judgment during the building renovation to meet the higher standards. Apart from simply complying with the mandates, an owner can leverage BIM for a plethora of economic, social, and environmental benefits. BIM must be extended from merely being used as an information model for design, construction, and maintenance of a building to including energy analysis as well. This is imperative so owners can identify ways to reduce resource consumption and waste generated by their buildings. They can also work to increase on-site renewable energy, build consensus, review
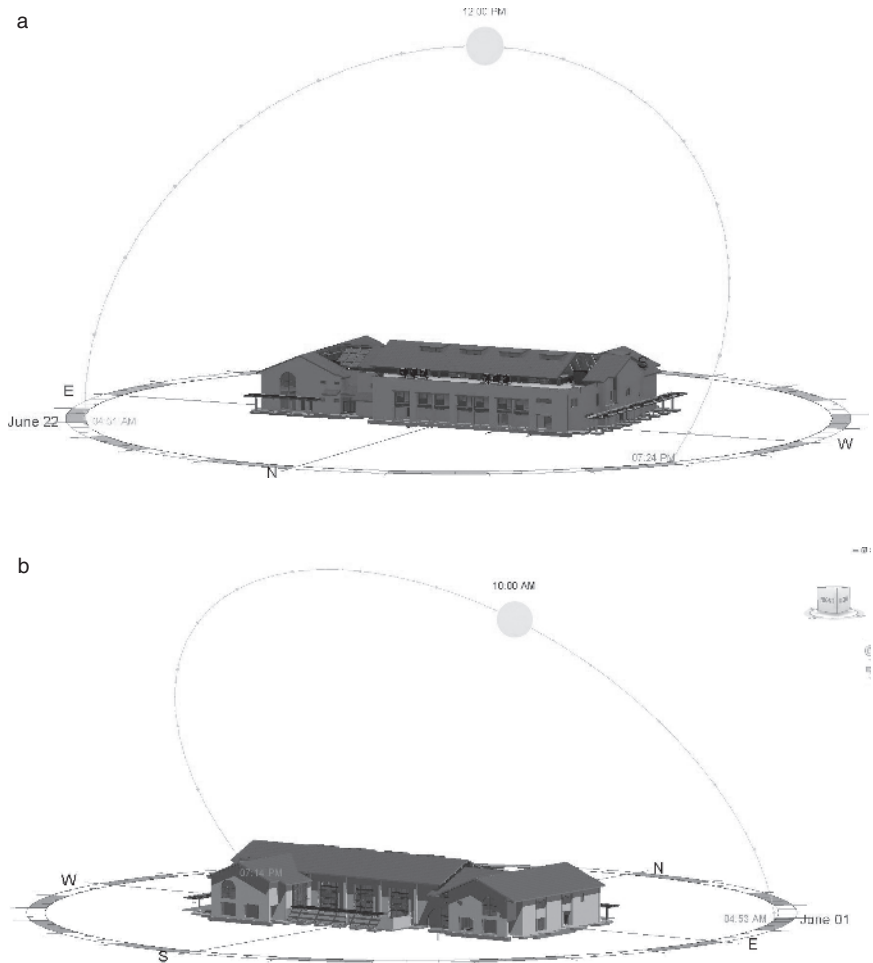
a

b

Figure 1.6 Building planned with green properties.

investment grade audits, increase building reputation in order to increase investor confidence, and also meet requirements for suitable design and energy efficiency for LEED certification.

During the design and development phase, BIM analysis tools can be used to analyze heating and cooling requirements and identify daylighting opportunities. This further helps with intelligent selection of major equipment that meets the exact building needs without any overages, which reduces energy use. An owner can include the local weather and electric grid data to estimate building consumption and carbon emission while at the same time planning for long-term investments.
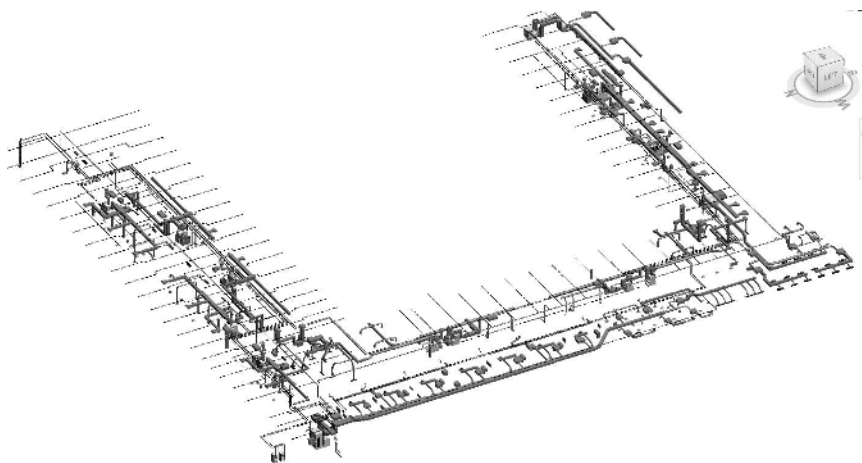
Figure 1.7 MEP duct piping.

Another significant advantage of using BIM data can be realized in water usage analysis. With more sustainable simulations, the use of recycled water for landscape irrigation and other purposes can be designed to minimize the cost and impact on water and waste-water systems. Evaluating storm water systems and simulating the performance of collection systems does not only make the building environmentally friendly but also helps secure extra credits for LEED certification.

During renovation, an owner often has to go back and forth with the architect to get the correct set of drawings; locate all the as-built information, manuals, and warranties for all equipment; and determine if the correct set of drawings is being used. Then the owner is forced to work with this set of drawings relying on a best guess. This is where the use of interoperable BIM software becomes highly beneficial. By laser scanning the building exterior and interior along with all the mechanical, electrical, and plumbing (MEP) ducts, pipes, and equipment, an as-built model can be created in no time. The scanned images can then be loaded with all the building information to perform an energy analysis. Rapid energy modeling enables building energy assessments with smaller budgets and a shorter time frame. The model re-created from the scanned images can also help to screen for high-carbon-emitting buildings for achieving carbon reduction. (See Figure 1.7.)

Figure 1.8 BIM showing how an owner can view the hallway of a building.

For an owner that has multiple buildings, it becomes easier to assess and analyze the energy performance of individual buildings and perform a complete evaluation of the environmental and financial impact before making any decisions. This evaluation provides a better understanding of the performance of the owner's entire portfolio. This helps prioritize the overall modernization and renovation programs while also helping to focus on the buildings with highest impact.

By using BIM modeling and analysis tools, information about a building can be presented at any time with high accuracy. A building owner can feel more confident about its building and present a proposed modification with higher clarity to the other stakeholders and decision makers. With a BIM model, the ultimate decision makers can virtually walk through the building to see the modifications and feel the spaces. This provides them with a better understanding of the project and builds consensus on any issue that may arise. Figure 1.8 shows the virtual view of the hallway of a building.

Preventive Maintenance

An owner has more than just design and construction incentives to implement BIM in the construction process. BIM is a digital representation of all the design, construction, and facility information

that is carried over from one party to another and finally delivered to the owner. BIM software creates a database that contains a data repository that can be used for purposes that vary from analysis and benchmarking to facility maintenance and management. This data can also be linked to other data or data sets for interpretation. There is absolutely no limitation on how much value a BIM can deliver to the owner. BIM enables data management of the entire building and has the ability to update and retain all the information in multiple dimensions. If the goals of a BIM implementation on a project are identified in the earlier stages, an owner can customize the data entry in the building elements to any level of development. For example, asset identification could be provided to allow an owner to schedule and track assets for depreciation. Any data regarding building elements can be entered in nongraphical form and later can be identified and linked with any maintenance and management software. The data can later be used for predictive or preventive maintenance. A schedule that will create an alert for any mechanical part that requires attention at a particular interval of time can be created. BIM can also generate as-built floor plans and elevations and produce data regarding paint colors for the accent wall in the executive conference room on the eleventh floor for any renovation work. If created correctly, BIM can also generate a warranty list for maintenance, such as locating the equipment maker, expiration date, and other information related to that particular equipment's maintenance.

Facility transition and space reallocation occur on many renovation projects. The facility manager typically works from (or perhaps has to track down from the architect) a set of as-built drawings that may or may not be accurate. The accuracy of these drawings usually depends on the building's age and the number of tenants that have occupied the space. Even worse, in the absence of as-built drawings, facility managers end up redrawing the space, which wastes time and energy in creating what would have already existed if there had been a BIM of the building. If the as-built records do not exist, dimensional information can easily be captured using 3-D laser scanning devices. Many facility managers who execute frequent moves find it easily justifiable to capture as-built information and build it into the BIM. In cases where tenants do not own the building, they can greatly benefit from the BIM provided by the owners to manage their own spaces.

Figure 1.9 Walk-through of a space.

BIM provides an improved 3-D visualization of the space throughout the life cycle of the building. The database of the BIM model can be linked with spatial management software. This software allows three-dimensional planning and can even include a virtual walk-through of a space, as shown in Figure 1.9. Owners can see and track assets through multiple moves over time. In cases like insurance claims or dispute resolution, it is incredibly helpful for an owner to reproduce what a building looked like in previous years before any remodels and expansions took place.

The BIM data repository also allows for analysis of all the decisions made in the past for any evidence-based design in the future.

CHAPTER SUMMARY KEY POINTS

- BIM is a digital database of physical and functional characteristics and information about a building that can be viewed in more than three dimensions.
- BIM enables an organization to build the building as it would be constructed on-site to help eliminate many of the inefficiencies of the construction process.
- The data-rich model can be used throughout the life cycle of a building.

- BIM can be used for creating as-built documentation for existing buildings, space reporting, spatial management, and tenant management as well as evaluating how well a proposed design meets the program requirements.
- Owners know all of the facts and numbers, yet they still accept the price of overall construction waste and build it into their estimate, budget, fee, contingency, and so on.
- Building owners hold special initiatives to implement BIM for the construction and maintenance of the building.
- Owners can protect their own interests and achieve their goals by modifying this whole arrangement and engaging the entire team to work outside the norm and under one umbrella by adopting new methods of project delivery.
- To improve efficiency in project delivery, the entire process must achieve a high level of coordination through better integration of information and process optimization.
- Integrated project delivery (IPD) is the reinitialized method of project partnering that utilizes the talent, experience, and input of all the team members from the beginning of the project.
- When implementing IPD, all team members need to think outside of the box to implement BIM to its maximum capacity.
- The IPD process is usually applied throughout the life cycle of the project, from design to fabrication and to the completion of the project.
- With an IPD, there is mutual risk and reward for the team.
- The lean process is the process or philosophy of reducing waste (time, material, and labor) and increasing value.
- Typically, the waste that is reduced in the lean process is change orders, poor information flow, rework, and the like.
- A general misconception is that IPD is required for BIM to be effective.
- The lean process reduces the overall cost of a project by identifying issues at a time when they are still inexpensive

to correct or at a time when the value to the owner can be determined.

- BIM provides owners with decision support data so they can better understand the true value of a design change prior to the construction process.
- User experience is scientific, and, in most cases, the user community is fairly predictive.