An Introduction To Building Information Modeling (BIM)

A Guide for ASHRAE Members

Revised November 3, 2009

Table of Contents

BIM Steering Committee

Dave Conover (Chair)
Dru Crawley
Stephen Hagan
Dennis Knight
Charles S. Barnaby
Chuck Gulledge
Rob Hitchcock
Steven Rosen

Additional Contributors To this Guide

Brian Emtman
Gordon Holness
Don Iverson
Mark Palmer
Chris Wilkins

1791 Tullie Circle, N.E., Atlanta, Georgia 30329
www.ashrae.org

Foreword

This Guide is intended to provide ASHRAE members with an introduction to Building Information Modeling and Building Information Models (both known as "BIM"). It is intended to serve as a starting point for those members considering adopting BIM tools and applications as part of their business practices. BIM is about integrating design and construction processes, about making them interoperable, and about the software tools needed to achieve that. It explores the benefits, costs, risks and rewards associated with BIM, interoperability and integration. In addition, for those members already applying BIM and BIM-related technologies, it may provide ideas to help them expand their services into new markets and unearth new opportunities.

The Guide identifies the current state-of-the-art of the industry with respect to software applications and related protocols, and provides additional resources and suggested reading material for members planning a transition to BIM. Because of the rapid evolution of technology, the Guide is intended to be a living document, and ASHRAE members are encouraged to share their experience to help update and improve it over time.

The greatest value of Building Information Modeling to the construction industry and to ASHRAE members may be its potential to reduce cost, increase productivity, reduce errors and improve the quality of our work products and to improve the built environment. As such, it can be a valuable tool in facilitating successful collaboration and coordination during pre-design, design, construction, and operation and maintenance of both new and existing buildings.

BIM applications will be essential to successful Integrated Building Design (IBD) and Integrated Project Delivery (IPD). IBD and IPD will also play a critical role in achieving our goals of reducing energy use, minimizing waste and delivering better buildings.

BIM will also be valuable to creating a sustainable built environment. Sustainability is a major focus of the Society as noted in its Strategic Plan and in all subsequent developments—Vision 2020, Standard 189.1 (High Performance Green Building Standard), Standard 90.1, the Advanced Energy Design Guide series (AEDGs), and every other publication and initiative we develop as we aim toward producing net-zero energy* buildings.

ASHRAE will play a significant role in the evolution of BIM and integration in the built environment by committing the resources and developing specific goals to establish comprehensive, consistent HVAC&R terminology, data dictionaries, rule sets, and schema for its Handbooks, Standards and Guidelines to support the HVAC&R and building industry. The establishment of an ASHRAE Building Information Modeling and Interoperability Steering Committee (The BIM Steering Committee) under the Society's Technology Council is an excellent start. It indicates recognition by ASHRAE of the role this technology can play in the development of better buildings.

As new educational programs, technical papers, and other publications are developed by ASHRAE and others, there is a need to be cognizant of the bigger picture and the new methods for the design and delivery of high-performance and sustainable built environment. BIM, interoperability and integration will significantly impact almost everything ASHRAE and its members do, as a technical

* See ASHRAE Vision 2020 at: www.ashrae.org/vision2020 for the ASHRAE Vision 2020 Ad Hoc Committee.[1]

society or as engineers, including the processes of developing, delivering and using ASHRAE standards and guidelines.

It is a goal of this guide that by reading this material a “light” will come on and the reader will realize some aspects of that integration already exist in much of what we do every day, and that BIM, integration and integrated practice can be implemented now without waiting for someone to “finish it first.” It will never be finished. There will always be room for improvement and innovation. If we wait, we will just get left behind.

Return to Table of Contents

BIM Terminology and Definitions

To explain the benefits and opportunities offered by BIM and integration, it is essential to develop a consistent vocabulary and set of definitions as a basis for the discussion.

The following definitions are given in the context of their use in this Guide. Definitions used in this document are presented to promote understanding in a narrative fashion and in a manner such that they build upon and support one another in the description of BIM, integration and interoperability. They are not presented in alphabetical order and do not try to describe every possible use of the word or term. Where the definition has been taken or adapted from a dictionary or other published material, the specific reference is indicated at the end of this Guide.

Building Information Model

A Building Information Model is a digital representation of the physical and the functional characteristics of a facility. As such it serves as a shared knowledge resource for information about a facility, forming a reliable basis for decisions during its life cycle from inception onward.[2] Creating a BIM is different from making a drawing in 2-D or 3-D CAD (see subsequent definitions). To create a BIM, a modeler uses intelligent objects to build the model.[3]

Building Information Modeling

Building Information Modeling is the human activity of using BIM software and other related software, hardware and technologies to create and use in a building information model.[4]

3-D BIM

See the definition of Building Information Model. A model that includes three dimensional (3-D) shape information and does not include the 4-D and 5-D characteristics described below.

4-D BIM

A 3-D BIM that has objects and assemblies that have schedule and time constraint data added to them. The information can be contained in the BIM or can be linked or otherwise associated (integrated and/or interoperable) with project design and construction activity scheduling and time sensitivity estimating and analysis systems.[3]

5-D BIM

A 4-D BIM that has objects and assemblies that have a cost dimension added to them. The cost information can be contained in the BIM or can be linked or otherwise associated to the building objects.[3]

2-D/3-D CAD

Two dimensional or three dimensional, Computer Aided Drafting is equivalent to conventional drafting, only performed on a computer. Unintelligent points, lines and symbols are used to convey design intent or detail construction means and methods. Most often plotted onto paper media and published in that form for drawings and specifications and delivered to the owner, contractor and reviewing authorities and agencies for approval and actual construction.[3]

Parameter

A quantity that is constant under a given set of conditions (rule set), but may be different under other conditions. For example: a duct penetrates a non-rated steel stud and gypsum board wall, and the annular space of the penetration is sealed only with caulk. If you change the wall to a 2-hour rated concrete fire barrier (new parameter) the duct still penetrates the wall, but in a different way, with a UL listed fire damper.[5]

Intelligent Object The object (or set of objects) represents not only the geometry required to represent the component or assembly graphically (visually) but also has the ability to have much more information about that object associated with it or related to other intelligent objects associated with it. Think of the geometric parameters of the object as being only one of many fields in a database that describes the visual features and characteristics of the object. Other parameters might include variables such as how the object may change (a rule set) when something with which it is associated changes. For example, if a relationship is established between a duct and a diffuser that are connected in the model and assigned a specified airflow and the modeler (engineer, designer, etc.) decides to change the specified airflow of the diffuser then the duct size and diffuser, neck size automatically (parametrically) are adjusted to accommodate the new specification, and pressure loss calculations throughout the entire duct system are automatically updated at the same time.

Parametric Rule based relationships between intelligent objects that enable related properties to be updated when one property changes.

Integrated Integrated data processing is that which has been organized and carried out as a whole, so that intermediate outputs may serve as inputs for subsequent processing with no human intervention. The same can be said for any human activity or process (see integrated practice). Note that integrated and interoperable are not mutually exclusive, but they can be. A system or process can be integrated within its own boundaries, yet still not be interoperable with other external systems or processes that could benefit from the use of data or information contained within the first system.[5]

Integration *Human activities and data processing*—The incorporation of working practices, methods, processes, and tools that creates a culture in which individuals and organizations are able to work together efficiently and effectively.[4]

Integrated Practice Uses early contributions of knowledge through utilization of new technologies, allowing Architects (Engineers, Owners, Contractors, Manufacturers, Firms, Individuals, Communities) to realize their highest potential as designers and collaborators while expanding the value they provide throughout the project life cycle (adaptation of definition in original publication cited). Essential to integrated practice is the elimination of waste and duplication by capturing knowledge and information one time, using it for any purpose necessary without losing it in the process and adding to it (creating new knowledge) over time.[4]

Interoperability In the context of BIM, IBD (Integrated Building Design) and IPD (Integrated Project Delivery), defined as the ability to manage and communicate electronic product and project data between collaborating firms' and within individual companies' design, procurement, construction, maintenance, and business process systems.[6]

Data Exchange Specification An electronic file format specification for the exchanging of digital data. They can be proprietary or open source and can be developed and promulgated by anyone.

Data Exchange Standard A data exchange specification developed and balloted by a standards developing organization for the purpose of standardizing electronic data transmitted between different software applications.

IFC Industry Foundation Classes (IFC) is a vendor neutral, open data exchange specification. It is an object oriented file format developed for the building industry and is commonly used in Building Information Modeling to facilitate interoperability between software platforms. IFC was originally developed in 1995 by a group of American and European AEC firms and software vendors through the International

Alliance for Interoperability (IAI). Since 2005 it has been maintained by building SMART International.[7]

XML Extensible Markup Language (XML) is a general-purpose electronic text tagging specification for creating custom markup languages. XML was recommended by the World Wide Web Consortium (W3C) as an internet standard in 2008. It is classified as an extensible language, because it allows the user to define the markup tags. XML's purpose is to aid information systems in sharing structured data, especially via the Internet, to encode documents, and to serialize data. XML is a free and open standard. There are many extensions and proprietary adaptations that exist.

gbXML The Green Building XML schema (gbXML) was developed to facilitate the transfer of building information stored in CAD building information models, enabling integrated interoperability between building design models and a wide variety of engineering analysis tools and models available today. gbXML has the industry support and wide adoption by the leading CAD vendors and HVAC software vendors. With the development of export and import capabilities in several major engineering modeling tools, gbXML has become a defacto industry standard schema. Its use dramatically streamlines the transfer of building information to and from engineering models, eliminating the need for time consuming plan take-offs. This removes a significant cost barrier to designing resource efficient buildings and specifying associated equipment. It enables building design teams to truly collaborate and realize the potential benefits of Building Information Modeling.

LCA Life-Cycle Assessment is the process of evaluating a component, product, assembly, building, etc., and their development from the moment of extraction of raw materials, transportation, processing, manufacturing, use, recyclability and disposal and assigning a value or assessment of its cumulative and ultimate social, environmental and economic costs, benefits and impacts. This is often referred to as a "cradle to grave" or "cradle to cradle" assessment.

Return to Table of Contents

The Benefits of Building Information

To understand the benefits of BIM to our industry and ASHRAE, we must explore some of the global benefits of BIM and discuss the direct benefits to ASHRAE and its members of embracing and adopting BIM, integration and interoperability.

Globally one of the great advantages of Building Information Modeling is the ability to create an accurate model that is useful throughout the entire life of the building, from initial design through occupancy and operation (see definitions). Ideally, a BIM would be created in the early stages of the design, updated as the design is refined and used by the construction team, and refined continuously as the facility is built. Post-occupancy, the BIM would be used by the owner and owner's maintenance team to improve understanding of building operation and to make adaptations, renovations, additions and alterations to the building faster and for less cost than through traditional processes. Future benefits may include linking manufacturers' R&D databases, which will be discussed later in this guide. In addition, operating level BIMs may be linked through integrated and interoperable pipelines to local and national emergency response and disaster management systems to help improve life-safety, save lives and mitigate damage.

The power of BIM can be realized though its ability to allow the whole building to be optimized in lieu of optimizing individual components. Each discipline and trade benefits through integration and optimization within a BIM and becomes more efficient by providing parametric responses to single discipline changes through the use of consistent data sets for calculation and decision making. The work of the HVAC industry has an impact on every other design and construction discipline and trade including the following: architecture, electrical engineering, lighting design, roof and envelope consultation, food service, fire protection, civil engineering, structural engineering, security consultants, acoustical engineering and others. BIM can benefit these associated and complimentary disciplines and trades through precise interdisciplinary coordination using parametric geometric modeling. However, much of the existing software, such as load calculation, plumbing, piping, lighting design and life-cycle assessment tools, only receive input data from the BIM at this time and are not fully parametric. Software and hardware developments that will allow adjustments and fine tuning of the calculations via changes in the BIM and vice versa that would result in optimizing the BIM in real time will be available in the near future.

The benefits of BIM are evident in its capability of capturing, organizing, integrating, maintaining and growing the vast amount of knowledge, data and information required to conceive, plan, design, construct, operate, maintain, adapt, renovate and, finally, beneficially deconstruct a building at the end of its life cycle.

The HVAC&R industry impacts building owners, users, regulatory agencies, legal, finance, operation and maintenance, the environment, and community. BIM can benefit project participants and these entities through improved multidiscipline collaboration to achieve optimal solutions, interference checking prior to construction, reduced errors and omissions, automated code/regulatory reviews, accelerated permitting, and earlier beneficial occupancy, leading to enhanced return on investment (ROI) for the building owner/developer.

Real-time monitoring of a building's temperature, humidity, ventilation, air quality, pressurization, isolation, compartmentation, and occupant location integrated into the BIM can benefit first responders in public health, safety, fire, law enforcement and disaster recovery to help save lives, protect property, and mitigate environmental and property damage.

During design and construction all disciplines and trades involved on a project can benefit from using BIM through:

Early Collaboration

BIM fosters collaboration in the early phases of a project between team members through the use of consistent and more complete information more effectively than do traditional approaches. This allows design decisions to be made that optimize the whole building at a stage when they are far less expensive to analyze, rather than the traditional approach of optimizing individual components. This should minimize the need to make changes later in the design or during the construction process when even small changes can have enormous effects on both the construction cost and life-cycle cost of the building. *Figure 1* illustrates this concept.

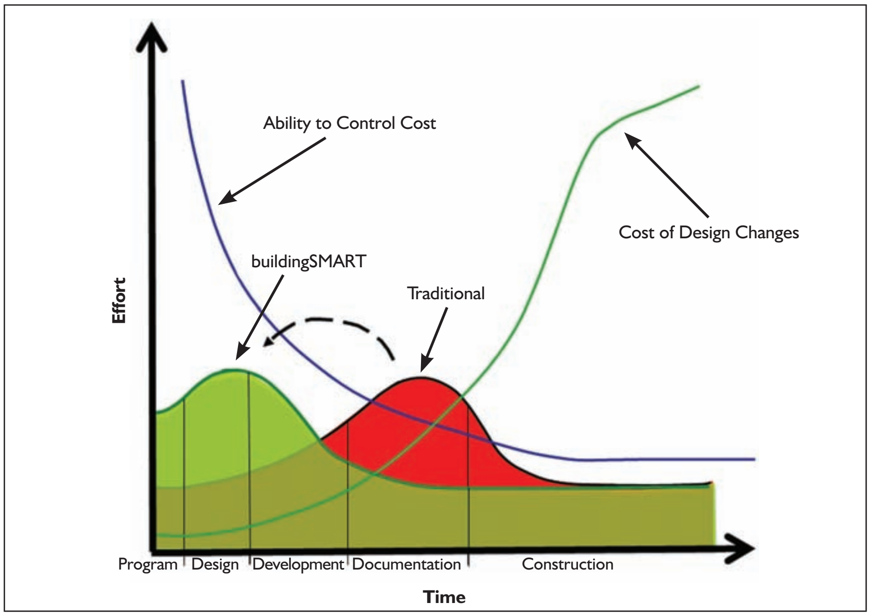

Figure 1: Effort versus cost curve. (Source: HOK, printed with permission.)

Parametric Modeling

Certain features, objects and components represented within a BIM can be related parametrically. (See definitions of parameter, parametric and intelligent objects.) Therefore, a number of related conditions can be updated by changing only one property. For example, if a diffuser is associated with a certain low-pressure duct, and that diffuser is moved, the associated duct will automatically relocate to the appropriate new position relative to the diffuser. Thus, not only can design changes be made earlier, they can also be made much faster and easier. This provides the designer greater certainty that all views have been updated with current information.

Quality

The ability of BIM to integrate multiple disciplines with the use of a common model means that coordination between team members is made easier, and design optimization and interference checking can be performed more frequently. This can be achieved through proprietary, single vendor solutions or through viewers and model checkers that can take advantage of interoperability and read, translate and understand multiple vendor file formats, possibly through IFC interfaces, domain specific XML tagging and other data exchange specifications and standards. This ability offers the potential for more thorough quality control in the design phase prior to construction activity beginning, which should result in fewer requests for information (RFIs) and change orders. For example, early interference checking and clash avoidance between ductwork and structural members facilitated by better 3-D visualization by designers and automated clash detection and model checking features that exist in the BIM or through interoperable applications can result in HVAC systems operating at lower static pressures, lower noise levels and lower horsepower than a system where the clashes are resolved in the field, by the "first trade there" method of clash detection, which can result in multiple offsets, cumbersome "work-arounds," changes in duct dimensions, waste and re-work in the field. Another benefit of BIM is the potential for ongoing commissioning. Real-time performance data gathering, verification and management allows for effective adjustments to systems to improve human comfort and safety and to optimize performance while minimizing environmental impacts

Economics

BIM can provide economic benefits for all stake holders. For example, investing in BIM technology by the design team frequently involves some initial expense; however, there is great potential to reduce design and production cost through more efficient use of time and better visualization. Contractors can benefit from the use of BIM through better coordination, better cost estimating and procurement management, use of the BIM for automation of off-site fabrication, and for better scheduling, which can provide cleaner and safer construction sites and shorter construction duration. The owner can benefit from the BIM through achieving greater certainty in outcomes with respect to project cost and time that can be better estimated when 4-D and 5-D BIM are integrated into the process earlier.

Sustainability and Climate Protection

BIM will play a major role in helping us meet the world's need for sustainable construction and climate protection. HVAC&R systems are one of the largest users of energy in a building. BIM will allow a design team to better take a "reduce and optimize" approach to reaching a client's and building project's sustainability and climate protection goals by focusing on reducing energy first. The most important aspect of providing sustainable high performance buildings is the attention to detail that can be given to the selection, optimization and use of materials and components based on whole building life-cycle assessment (LCA). A large component of an LCA is the building's use of nonrenewable energy sources. BIM allows the rapid and economical (relative terms) consideration of alternatives, what ifs, and game scenarios early in the evolution of a building to optimize the building's life-cycle impact.

For buildings to be sustainable, they must be adaptable. A building's materials, components, contents and systems should ultimately be 100% recyclable either through adaptive reuse, preservation, restoration, salvage, and/or traditional recycling processes. A building that serves as a school today should be able to function as an office building or medical facility in the future. A BIM is a living historical database of every material, component, assembly, and system used in the building. The BIM can contain design, construction, and life-cycle assessment information; operation, service and maintenance data; along with energy use down to the system and component level that could be used for intelligent strategic planning for the adaptive reuse or recycling of a building should renovation, restoration or demolition become necessary. The popular mantras "reduce, reuse, and recycle" will be better served through the use of BIM, integration and interoperability.

Benefits to the Industry and ASHRAE

Specifically the HVAC&R industry and ASHRAE can benefit from embracing and adopting BIM processes in many ways.

The HVAC&R industry is broad and expanding. Some of the disciplines and trades that fall under the category of HVAC&R include, but are not limited to:

- HVAC&R engineers;
- HVAC&R contractors;
- Building scientists;
- Energy modelers;

- Building performance modelers;
- Specification writers;
- Facility managers;
- Commissioning agents;
- Test and balance agents;
- Building automation integrators;
- Researchers;
- Students;
- Faculty; and
- Manufacturers of major system components (e.g., from refrigeration to piping, from distribution devices to valves).

For this guide, these disciplines and trades will be broadly described as the design professional, construction professional, manufacturer, software developer, academic, and ASHRAE Society. The benefits for each of these broad categories are described below.

Design professional: The greatest benefits of BIM to the design professional will be its fundamental effect on the process of design. By moving away from 2-D and 3-D CAD and paper-based review, analysis and work product delivery processes, BIM will help increase productivity, lower design cost and improve design quality. Increased productivity and lower design cost will be realized by using information about the building contained in the BIM to automate precise quantity, material and assembly takeoff, reduce the time required to perform HVAC&R load analyses, energy modeling, duct design, air distribution design, piping system design, equipment selection, cost estimating and specification production. Improved design quality will be achieved through greater visualization and, thus, better understanding of end results, more precise interdisciplinary coordination and clash and conflict avoidance prior to construction, reduced requests for interpretation (can also be referred to as requests of information) from contractors and, as a result, less coordination related change orders. BIM, integration and interoperability will allow the design professional to work in an environment that provides greater certainty of the correlation between design intent and the final construction and operation of the building.

Construction professional: Similar benefits as stated for the design professional will also accrue to the construction professional as a result of more precise and integrated design processes that include fabrication and constructability evaluations. In addition, the construction professional who learns to take advantage of a design level BIM, takes over its management and adds construction level details, subcontractor information, piece and part numbers and 4-D and 5-D data, will then increase productivity, lower construction cost, improve construction quality, better manage risk and enhance job-site safety. Increased productivity and lower construction cost will be realized by using information about the building contained in the design level BIM to automate precise quantity, material and assembly take-off, automate scheduling of crews, subcontractors, temporary facilities and manage procurement, delivery and fabrication processes. Improved construction quality will be achieved through greater visualization and, thus, better understanding of end results, more precise trade coordination and clash and conflict avoidance prior to fabrication and erection, reduced requests for interpretation to the design professional and, as a result, less coordination related change orders. BIM, integration and interoperability will allow the construction professional to also work in an environment that provides greater certainty of outcomes with respect to the final construction and operation of the building.

Manufacturer: The manufacturing industries have recognized the benefits of information management, computer-aided design and modeling, integration and automation for decades. In most cases, many manufacturing processes aren't as diverse or fragmented as the design and construction process. Manufacturers who adopt interoperable and integrated BIM technologies to promote their products and services to owners, design and construction professionals will accrue many of the same benefits previously stated. BIM provides mechanisms for the earlier use of supplier information for selecting products and assessing their installation, commissioning, operation and maintenance characteristics when making design and installation decisions. By providing product data that integrates with and is interoperable with design and analysis tools, detailing and specification systems, cost and scheduling systems, and procurement and construction management systems, manufacturers can better predict future manufacturing needs for their products, better control inventories and improve just-in-time manufacturing and delivery methods. BIM integration can also reduce the cost of creating and updating owner documentation for sales literature, shop drawings, product data, installation instructions, warranty management, training, commissioning, operation and maintenance by including links to the manufacturer's digital, Web-based product information. By taking this thought a little further, a manufacturer capable of gathering data, feedback and real-time information embedded in operating level BIMs will be able to use the built environment as a large research and development laboratory to monitor and improve existing products and create new products and opportunities.

Software developer: As previously stated, our technical knowledge base is doubling at the rate of almost once every two years. Web based applications, cloud computing, model servers, integrated project management and data repositories either exist now or are being developed and tested as this guide is being written. Great economic benefits and opportunities exist to software vendors who can develop interoperable applications, both proprietary and open source solutions, that respond to the changing needs and demands of the design, construction, owning, operating and maintenance industries and are capable of keeping up with and maintaining compatibility with the rapid advances that are constantly occurring in science and technology.

Academic sector: As our knowledge base expands and more reliable data and metrics are captured from better connected databases and operating level BIMs, researchers will be able to provide better, more focused study, innovations and solutions. They will be the leaders in creating new knowledge to benefit our industry, the community and the environment. BIM is also a training tool for future engineers.

ASHRAE: The combined benefits of BIM to every discipline and sector defined above will all accrue to the benefit of ASHRAE. Converting the combined knowledge base contained in our standards, guidelines, handbooks and other publications into digital computer-proccessable resources, so they can be integrated with building information modeling software, will make ASHRAE more valuable to its members and all of humanity.

Return to Table of Contents

Getting Started With BIM

First Steps

As with any business decision, the transition to BIM and integration should begin with evaluation of existing practices and the development of a strategic plan for process change and implementation. The pathway to BIM and integrated practice does not have to occur overnight. Taking small, measured steps using disciplined thought and disciplined action will lead to maximum benefit. The following steps may be beneficial to help in developing your plan and guiding your transition:

1. Review the business process currently used to design and specify a building and its HVAC&R systems, whether it is paper based or computer based.
2. Take a hard look at exactly what you do, how you do it, the information flows, the sources of waste and inefficiencies, the software applications used, and what is produced. Be as thorough as possible at this stage. Just like with BIM and integrated design, applying greater emphasis on the early phase of the technology and process change and adoption cycle will result in better, more valuable and enduring decisions. Do this while the cost of changes is still relatively inexpensive, before workflows have been changed, and before additional software and hardware systems have been purchased.
3. Review relevant policies, procedures, design standards, graphic standards, project management procedures, documentation creation and storage, archival and retrieval processes, software applications, and project delivery methods currently being applied in your business.
4. Determine whether each process is manual, computer based, stand-alone, integrated and/or interoperable with current systems and potential purchases.
5. Determine where duplication of effort and duplication of information input is occurring. According to the buildingSMART alliance, information about a project is re-entered an average of seven times during the project life.[†]
6. Ask tough questions:
   - Is this process needed or essential?
   - If the process were eliminated, what would happen?
   - Do duplication or other types of waste exist and how can it be eliminated?
   - Would capturing that information one time and adding it to a BIM or integrated application, and updating it and maintaining it over time improve the quality of your work products, lower cost, and improve productivity?
7. Take this opportunity to do a little "clean-up" and optimize existing processes and systems by eliminating already outdated or antiquated procedures and unnecessary steps. A resource for guiding this type of analysis and collecting quantitative data is available in Annex B of the NIST Report, GCR 04-867, Cost Analysis of Inadequate Interoperability in the U.S. Capital Facilities Industry.
8. Assess how you and your firm or business is currently integrated and how to leverage existing and new technology to be more efficient and productive.
9. Do a skills inventory of employees, consultants, clients, contractors, and users.
   - Determine the technical skills that already exist within your organization and within the organizations of your associates and colleagues.

† From buildingSMART alliance web page: Frequently Asked Questions About the National BIM Standard™, http://www.buildingsmartalliance.org/nbims/faq.php.

- Determine what basic training and education may be required to bring the entire staff from senior management and project managers to designers and production staff to a level of complementary understanding of the anticipated process changes, cost constraints, time constraints and the expected results.
- Determine if existing team members in-house and outside the firm have the same goals and objectives regarding making the transition as you do and if their time frame for implementation is compatible with your anticipated schedule.
- Spend time discussing your plans with your clients, educating them and making sure the transition you intend to make fits your clients' business needs and will create greater value and certainty for them than you are able to deliver to them now. This is an essential step.

10. Research and test drive as many different potential solutions as possible before settling on a single or multiple solutions that fit your needs. At this stage, consider using the three-day rule for making quick evaluations.[4]

In the book "Big BIM, little bim," author Finith E. Jernigan, AIA, suggests that the search for new applications can happen relatively quickly and that it should only take about three days to evaluate a new major product or application and determine whether it is useful for your intended purpose. He recommends that you should:

- Spend time going through the tutorials or attending the vendor's one-day introduction training.
- Take a real world project from your practice and use the new product to develop the project to a basic level of presentation that you would be "proud" to deliver to your clients.
- Be able to create, at the end of the three-day trial, a basic model of a typical project that you and your firm routinely creates and that you already have a high level of knowledge and competence in developing prior to applying the new technology.
- Be able to extract basic information from the graphic and analytic models after three days for preliminary cost estimating (i.e. detailed quantity extraction) and extraction of data required for preliminary energy analysis.

Mr. Jernigan's mantra for better business decisions is to "Fail fast and move on." If the technology does not fit your client's or your business needs, do not adopt it.

- Determine whether a single solution or multiple solutions will be required.
- Determine whether integration and interoperability exist in the proposed solution. If so, to what degree?
- Determine if the solution exists in commercially available off-the-shelf technology or will the technology have to be developed?

Finally, Mr. Jernigan suggests that "if the software does not improve your process and if you are not comfortable working with the software, the vendor, the support network, etc., you should not buy it.

11. Develop in-house matrices similar to those seen on the back of software boxes in the office supply store, which can be very useful in quickly analyzing and evaluating the costs and benefits of various solutions being considered and conveying the results to management and outside parties such as banks and investors.
12. Ask vendors questions about what the total cost of transition may involve, including, but not limited to: the actual software cost; should the software be purchased as single seats or as network versions; what is the cost of training; are consultant or third-party costs involved for training and data conversion; are there recurring subscription service costs; are there technical support costs

and limitations, and what are the best ways to manage files and collaborate with clients and outside consultants.

13. Sketch out an implementation plan once decisions have been made on what solutions and application(s) will be purchased and what existing processes will be changed. The plan should include these actions:
    - Determine what libraries and databases exist that can be used within the chosen solution.
        - Do those libraries and databases exist in-house?
        - If not, can in-house staff quickly create and develop them from existing information?
        - Will they have to be purchased from the original software developer or from third-party vendors?
    - Assess the time and cost required to convert, input and capture existing knowledge, standards and operating practices that are worth retaining.
    - Assess the time, cost and commitment required to keep the new processes and systems up-to-date and maintained.
    - Assign champions within staff and manage the roles, responsibilities, accountability and evaluation metrics that will be used to determine the progress and success of the transition.
    - Create a process of continuous maintenance and review starting at step one above, at least annually, with a goal of continued improvement. This is important to obtaining maximum benefit from any new process or change and is often overlooked or deferred in the name of production, which usually results in stagnation and loss of productivity.

Software Tools and Early Collaboration

All of the attributes and benefits described by BIM, integration and integrated practice in the definitions and other discussions throughout this document, including much of the graphic and analytic modeling needed to design and construct a building, can be achieved with proprietary, single software vendor means. However, the breadth of the scope and complexity of the design, construction, owning, operation and maintenance industries, both across many disciplines (architectural, civil, mechanical, electrical, etc.) and across the life cycle of projects and capital assets, implies that many applications from many sources (some already in commercial use, others still to be developed) must be integrated and connected.

Interoperability between operating systems, BIM software, engineering analysis software, cost estimating software, scheduling software, property management software, energy management software, and others is a necessity. Interoperability requires data exchange specifications. These specifications can be established in several ways. First, data mappings can be specified between different data representations in a pair-wise fashion (translators) for every possible variation in format (see *Figure 1* in the next section).

Alternatively, everyone in the industry can voluntarily adopt a common data representation and consistently use that representation in all instances. Since pair-wise data mapping is difficult to manage over time, and voluntary adoption of a common data representation is unlikely, a third approach is to develop industry-wide standard data representation specifications and encourage participants to map their internal representations to this standard.

The BIM Handbook[8] lists over 70 different software companies offering several hundred different building design, construction and operation related software packages that already offer some level of BIM capable interoperability.

Many applications, tools and capabilities discussed in this Guide are available and are being used and applied now by design and construction firms, researchers, and public agencies in the U.S. and around the world. A partial list of some currently available software tools and applications available for use in BIM and integrated practice is included in Appendix A. The list is not intended to be definitive and inclusion on the list should not be considered an endorsement of any products by ASHRAE.

Many more applications can be found in the publications listed in the suggested reading and references of this Guide and on the Internet. Remember to follow the suggestions in the First Steps section when evaluating and considering new technologies.

Return to Table of Contents

What Others Are Doing and How to Get Involoved

Within ASHRAE, many Technical Committees (TCs) and Standing Standards Project Committees (SSPCs) are already engaged in conversations both inside and outside the Society. Some of this activity includes:

- TC 1.6 – Working with the National Institute of Standards and Technology (NIST) and Carnegie Mellon University (CMU) in coordination with SPC 166 on the development of a process and tools to:
    - Identify and resolve overlaps, ambiguities, and conflicts among definitions in ASHRAE standards and guidelines (with an initial focus on Standard 90.1 and other ASHRAE standards related to the "thermal view" of a building).
    - Produce a common data dictionary for use in creating future standards and guidelines as computer processable resources.
- GPC 20P – Development of Guideline 20, which will establish procedures for documenting HVAC&R work processes and data exchange requirements to support interoperability.
- TC 1.5 – Related Research work including 1354-RP Generic Common Interoperabilty data for the HVAC&R Industry Applications and 1468-TRP Development of Reference Building Information Model (BIM) for Thermal Model Compliance Testing.
- TC 7.1 – Multiple BIM related activities including:
    - Seminars at ASHRAE meetings;
    - Journal articles;
    - Initiation of research on BIM for Operation & Maintenance activities; and
    - Addition of BIM content to the IBD chapter of the Applications Handbook.
- BIM SC – Coordination of BIM activities within ASHRAE and assignment of official ASHRAE liaison to other organizations to report on BIM activity outside ASHRAE.

ASHRAE members can become active in these groups by visiting the ASHRAE Web site, joining these committees as a corresponding member, attending the committee meetings at the Annual and Winter Conferences, and subscribing to a committee's Listserv (where available).

There are organizations actively working to provide resources for BIM users, develop governing specifications and standards, and direct the future of the technology. One of the most active of these organizations is the buildingSMART alliance. This organization is a council of the National Institute of Building Sciences (NIBS), and is the new "home" for developing the National BIM Standard (NBIMS). The buildingSMART alliance serves as the North American Chapter of buildingSMART International, which is a consortium of 30 countries formerly known as the International Alliance for Interoperability (IAI). A number of countries are very active in the international organization including Scandinavia and some Pacific Rim territories.

The buildingSMART alliance is focused on the integration of all disciplines related to the life cycle of facilities, including engineers, architects, owners, governments, developers, users and many others. The intent is to build a bridge between the private and public sectors and encourage collaboration among all parties. The alliance coordinates a wide variety of projects aimed at improving BIM. Of the many projects currently under way throughout the industry, some examples include:

Construction Operations Building Information Exchange (COBIE): a specification to identify appropriate content transfer at each project stage.

SMARTcodes: technology that would enable software to perform some aspects of plan review and code compliance checking.

Distance Learning: a project to transition BIM education from merely unrelated uncoordinated seminars to an actual curriculum by assembling educators and identifying teaching strategies. You can learn more abort the buildingSMART alliance and participating groups and organizations at: http://www.buildingsmartalliance.org/projects/active projects.php.

Return to Table of Contents

The Future

The use of BIM, in conjunction with the other new paradigm changes being adopted by the building industry,[‡] is transforming the way buildings and building systems are designed, manufactured, assembled, commissioned, operated and maintained. Decades of research into modeling and simulating building systems and anticipating occupant behavior have led to the current state of activity. Rapid advancements in our ability to capture existing information and create new knowledge from it will enable stakeholders in the building industry[§] to develop and evaluate more alternatives with greater certainty and earlier in the design process, resulting in the faster delivery of new levels of building performance and quality than ever before seen.

The increased use of information technology by all stakeholders in the building industry will also catalyze changes in roles, responsibilities, work processes, opportunities and market shares. For some organizations, this will include the expansion of services including, but not limited to:

- Architects, engineering and construction firms providing commissioning and management of the "as-built, as-commissioned and operated" building information model.
- HVAC equipment manufacturers providing automated equipment selection and sizing software applications, which produce "complete" models of the selected equipment (including functional, physical, performance, connection, and installation information) to be included as part of a building information model.
- Building component fabricators using industrial engineering, automation, modularization and advanced BIM software applications to expand the scope of their work packages, the complexity of subassemblies and the globalization of fabrication.
- Building controls manufacturers designing, delivering and installing self-configuring, intelligent control systems that integrate system performance models to respond to changes in building geospatial configuration and use.

For those organizations that recognize the growth opportunities, these changes will be beneficial. Those enterprises that ignore these changes and the necessary strategic and tactical planning will impede their future growth and, possibly, even jeopardize their survival.

Most organizations that are already using BIM have examined their existing work processes to determine how to best leverage information technology. Many organizations have yet to examine rigorously how their internal work processes interact with other organizations and to investigate possible improvements from re-engineering the work processes and the work packaging. A fundamental principle for the successful adoption of information technology is to first analyze one's work processes (both internal and external processes and information flows), define possible improvements enabled by these new technologies, assess the risks and benefits and to then determine the optimum transition strategy. This analysis should include the larger context of how the

‡ Examples include: integrated practice, integrated building design, integrated project delivery, life-cycle assessment, enterprise-wide supply chain management, lean construction and net-zero energy buildings.

§ Stakeholders include: architects, engineers, contractors, manufacturers, suppliers, building regulators, owners, researchers, software developers, security providers (public and private), emergency responders, disaster recovery specialists.

organization plans to survive, let alone grow in this new business environment. The industry, as a whole, must examine:

- Crossing organizational boundaries to overcome traditional divisions to enhance both building and project performance.
- Reorganizing design and construction processes to exploit the full potential of these technologies.

Early efforts at promoting the benefits of BIM, integration and interoperability and the adoption of information exchange specifications and standards oversimplified the challenges that must be overcome for individual firms to succeed. For the efficient and successful adoption of BIM in the HVAC&R industry, organizations such as ASHRAE are working with other organizations (e.g., American Institute of Architects, Association of General Contactors, buildingSMART alliance, U.S. Green Building Council, Construction Specification Institute, and International Code Council) to develop practical guidance to overcome the difficulties and identify viable increments of advancement and change to practices and tools.

Currently, most exchanges of BIM information require a human to select, package and then transmit the relevant building information to the appropriate expert or organization. In the future, new protocols for "business process choreography" will enable automatic interactions between information systems (requesting, selecting, sending, accepting, integrating, using, storing and responding), removing the need for human intervention and the time delays that can ensue. Achieving this level of integration and automation with the use of BIM will require educating and demonstrating to the building industry in the benefits of industry agreements on sharing business processes and how to convey business process and transaction profiles for automated search, authentication and use.

As the industry adjusts and adopts these technologies, work process and software tools will become more robust. This will require new ways of modeling and analyzing buildings and systems. Many of the simplifications employed for "drawing" building designs will be re-examined and possibly changed. For example, the simple issue of how to model thermal boundaries (internal and external) as part of preliminary energy analyses will evolve to where the intricacies of the effects of secondary boundaries (interstitial layers) and their effect on building performance will require changes in how engineers model buildings, spaces and systems. It will also change how software applications manage the varying degrees of complexity needed for different types of analyses.

In many cases, digital exchange and integration of design models, equipment specifications, sensor and control information, construction plans and related information has been and is being impeded by the absence of consistent vocabularies, identifiers and encoding formats for data exchange and for information generated and used by companies throughout the life cycle of facilities. Due to the lack of widely accepted data exchange specifications and standards that would harmonize and align data across "intersecting information domains," early efforts to solve information exchange and integration challenges across various disciplines and spanning the life-cycle phases of a building have had minimal success.

Achieving these capabilities will require some critical changes in the infrastructure for developing, delivering and managing digital information for the built environment. The building industry uses numerous engineering standards and a diverse set of industry vocabularies to describe and deliver constructed facilities. These information and knowledge resources are available primarily as hardcopy or text images. For some domains (e.g., HVAC and fire protection design), software applications have been developed to include semantics and logic from such standards. The professional societies that are the stewards for these engineering specifications and standards and industry vocabularies are beginning to recognize the importance of migrating these knowledge resources into computer-based formats that include the formalized logic and semantics that will allow them to be beneficial to BIM and integration.

Over the last decade, with the emergence of IFC-based building information models, it is possible to envision the creation of computer-based models of engineering standards and codes. Work is under way within ASHRAE to review the inconsistencies among the various glossaries used in ASHRAE standards and to initiate the development of a consistent data dictionary as part of transitioning ASHRAE standards from paper-based products to computer-based knowledge resources. As work proceeds with this initiative, ASHRAE is examining how to deliver computer-based ASHRAE standards, handbooks, publications and processes that will be aligned with the data dictionaries of peer organizations for the other sectors of the building industry.

All of these transformations will build upon a quickly changing landscape of information resources and services. The building industry is already grappling with the legal and intellectual property rights issues that are slowing the transition from hardcopy drawings to building information models as the legal record for design and construction deliverables for building project delivery. How these same issues are addressed to include all tiers of the project team, suppliers and local authorities must be resolved before the full potential of BIM and integration can be realized. This new world of BIM, integration ad interoperability will use an increasingly complex set of federated information resources. Research is under way to determine how best to align these vocabularies, data dictionaries, supplier databases, and building regulatory processes with advances in modeling and simulation. ASHRAE is monitoring these topics and current research to provide its members with the necessary guidance.

Return to Table of Contents

Conclusion

Building Information Modeling is clearly gaining momentum as the technology evolves and greater interoperability is possible between disparate software systems. The need for lower design cost, increased productivity and reduced errors and omissions, coupled with the rapidly emerging goals of green building/sustainable design and net-zero energy buildings and carbon dioxide emissions reduction, will require "whole building" fully integrated design, construction operation and maintenance. Beyond these objectives are traditional cost, quality, safety, and productivity goals not just for individual buildings but for facilities, communities, and cities. BIM can help provide that integration. More importantly, it can provide process enhancements that save money and by getting projects designed and built in a more timely fashion, enhance ROI and allow money that would have been wasted to be reinvested upfront toward a better building.

There is no question that the information technology required for these processes is complex, difficult to implement, and is straining the limits of designers' current hardware, software, and staff capabilities. Much more work must be done to enable the technology to be fully applied on a day-to-day basis, and the industry is still far from having an interoperable, federated system that can enable fully integrated parametric building and system design. The greatest opportunity lies with fully integrated, multidisciplinary A-E practices where BIM integration is being done as a continuum of the design process.

There are also tremendous opportunities for improved efficiency in the overall design and construction process. These efficiencies, coupled with the building owner/developer seeing the economic advantages of BIM over the short- and long-term, will continue to drive BIM technology forward. ASHRAE members can help guide the application and use of BIM technology as the building design, construction, commissioning and O&M process is changed by BIM and by information technologies in the coming years. The first challenges are in understanding what is happening, seeing the potential, and taking action to turn that potential into reality.

Return to Table of Contents

Additional Reading Suggestions

The following books, articles and trade publications are listed to provide the ASHRAE member with additional resources and research material to help increase their knowledge and understanding of the benefits, challenges, processes and applications discussed in this guide. They are listed in the suggested order of reading to provide the most beneficial understanding of BIM, integrated practice, integration and interoperability as it relates to our industry and beyond.

Reading this material either before a major purchase or adoption of a new business practice may reduce the cost and time required to implement these changes and improve the success of the transition.

- *BIG BIM little bim* by Finith Jernigan.[4]
- *BIM Handbook* by Chuck Eastman, et. al.[8]
- *ASHRAE Vision 2020*[1]

Return to Table of Contents

References

1. Jarnagin, R.E. 2008. *ASHRAE Vision 2020.* Atlanta: ASHRAE Vision 2020 Ad Hoc Committee.

2. National Institute of Building Sciences (NIBS). 2007. *National Building Information Modeling Standard* Version 1, Part 1, p. 21.

3. National Institute of Building Sciences (NIBS). 2007. *National Building Information Modeling Standard* Version 1, Part 1.

4. Jernigan, F. 2007. *BIG BIM little bim, The Practical Approach to Building Information Modeling, Integrated Practice Done the Right Way!* Salisbury, Md.: 4Site Press.

5. Parker, S. 1984. *McGraw Hill Dictionary of Science and Engineering.* New York: McGraw-Hill.

6. NISTIR 7417. 2007. August.

7. Wikipedia, The Free Encyclopedia, 15 Mar 2009, http://en.wikipedia.org/wiki/Industry_Foundation_Classes.

8. Eastman, C., et. al. 2008. *BIM Handbook, A Guide to Building Information Modeling for Owners, Managers, Designers, Engineers, and Contractors.* Hoboken, N.J.: John Wiley & Sons.

Return to Table of Contents

Appendix A—BIM Software Guide

This appendix provides a partial list of some currently available software tools and applications available for use in BIM and integrated practice. This list is not complete and will, in fact, be out of date almost immediately. The list is included simply to start educating readers of this Guide on the lexicon of the industry. It is not intended to be a definitive list and inclusion on the list should not be considered an endorsement of any products by ASHRAE.

Additional resources can be identified through a Web-based search engine using key words such as: BIM (for general information), BIM software (for product information), and HVAC design software (for HVAC related products including BIM). Other key words shown in the definitions section of this Guide may also be helpful.

Examples of Current Commercial Application Software

Organizations	Product	Web Site
Autodesk, Inc	AutoCAD MEP	www.autodesk.com/autocadmep
	Revit MEP	www.autodesk.com/revitmep
	Autodesk NavisWorks Manage	www.autodesk.com/navisworks
	Autodesk Green Building Studio	www.autodesk.com/greenbuildingstudio
	Autodesk Ecotect	www.autodesk.com/ecotect
	Autodesk Buzzsaw	www.autodesk.com/buzzsaw
	Autodesk Constructware	www.autodesk.com/constructware
Bentley Solutions	MicroStation Bentley Architecture Bentley Building Mechanical Systems AutoPipe AutoPlant Bentley Buidling Electrical Systems Hevacomp M&E Designer V8i Hevacomp Simulator V8i Bentley Tas Simulator V8i Bentley Tas Ambiens CFD	www.bentley.com
Bentley Systems	Architecture Structural Civil Mechanical Electrical Piping Instrumentation and Wiring HVAC Geospatial (GIS) and Facilities	www.bentley.com
Granlund	RIUSKA Integrated Building Solutions	www.granlund.fi/
Graphisoft	ArchiCAD 11	www.graphisoft.com
Wrightsoft	Right-Suite Universal	www.wrightsoft.com
CADPIPE	ArTrA BIM	www.artra.co.uk

Examples of Current Viewing Management Software		
Organizations	**Product**	**Web Site**
Bentley Systems Collaboration & Viewing Tools	ProjectWise Navigator	http://www.bentley.com/en-US/Products/Bentley+Navigator/
Progman Oy	MagiCAD	www.progman.fi
Navisworks	Jetstream 3-D (Open Protocol Management)	www.navisworks.com
Nemetschek	Integrated IT Solutions	www.nemetschek.com
Newforma	Project Viewing and Mangement	www.newforma.com
Solibri	IFC Optimizer–Data Storage and Transmission All Plan IFC Viewer	www.solibri.com

Examples of Current Model Checking and Code Compliance Software		
Organizations	**Product**	**Web Site**
AEC3UK	XABIO Octaga Player	www.aec3.com
CORENET	ePlan Fornax Viewer	www.corenet.ess.gov.sg/
DOE	COMcheck	www.doe.gov www.eere.energy.gov/buildings/tools_diectory/software.cfm
Solibri	IFC Optimizer Model Checker	www.solibri.com

Examples of Current Related Construction Management Software		
Organizations	**Product**	**Web Site**
Autodesk	Buzzsaw	www.autodesk.com
Bentley Systems	Project Wise	www.bentley.com
E-Builder	Web Based Project Management	www.e-builder.net
Newforma	Newforma	www.newforma.com
Primavera	Project Management	www.primavera.com

Examples of Other Technology/Schema		
Organizations	**Product**	**Web Site**
Ansys	CFX5 Computational Fluid Dynamic Software for Airflow Simulation	www.ansys.com
Cyra Technologies	Laser Scanning	www.cyra.com
Disco Systems	Laser Scanning USD-M2	www.usdm2.co.uk
Leica Geosystems HDS	Laser Scanning of Site Systems	www.leica-geosystems.com

Examples of BIM-aware Downstream Applications		
Organizations	**Product**	**Web Site**
Carrier	HAP	www.commercial.carrier.com
Elite	Chvac	www.elitesoft.com
Energy Design Resources	eQuest	www.energydesignresources.com
Trane	TRACE 700	www.trane.com
Wrightsoft	Right-Suite Universal	www.wrightsoft.com

Return to Table of Contents