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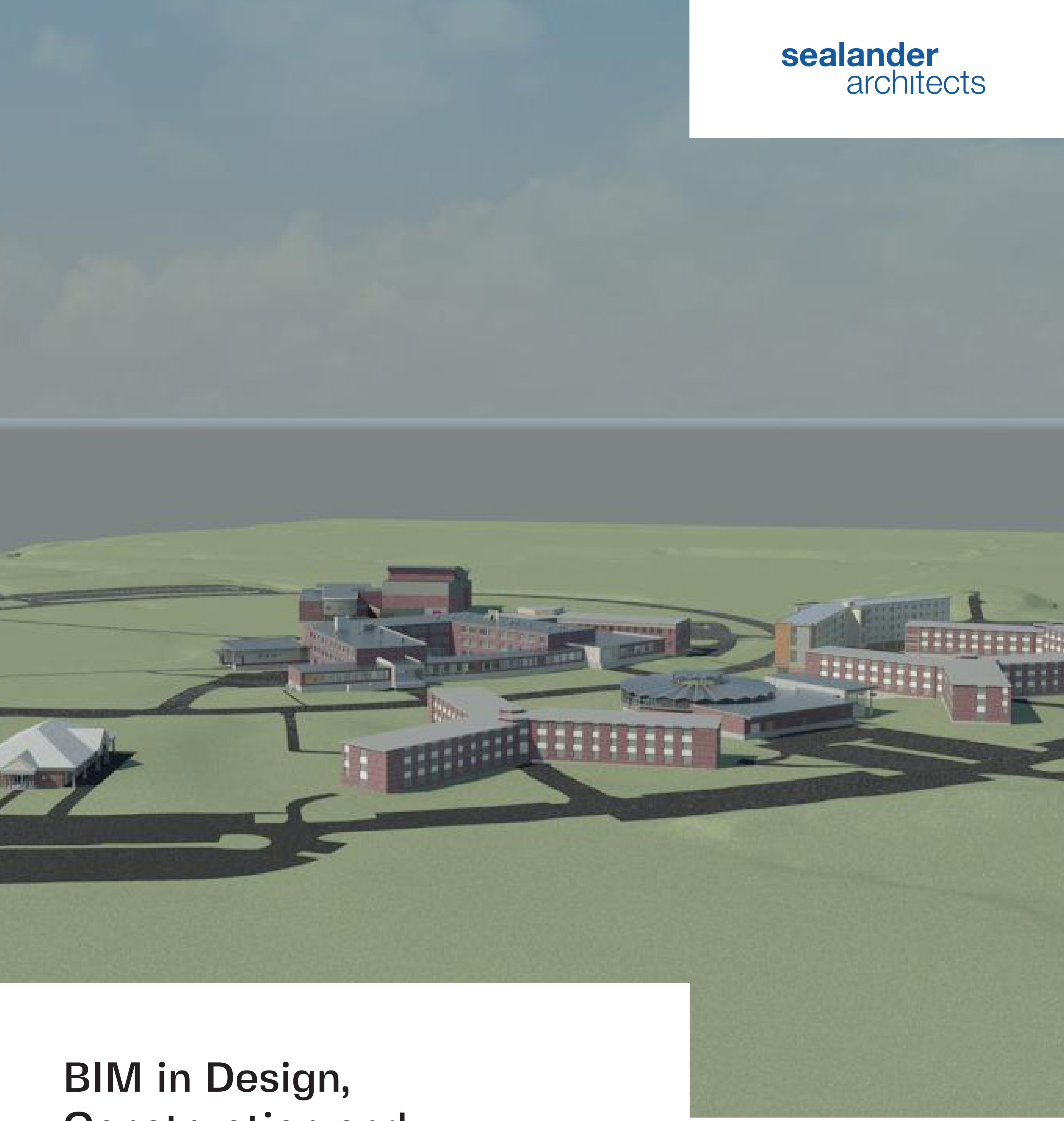

BIM in Design, Construction and Facilities Maintenance

AN OVERVIEW

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Building Information Modeling, or BIM, is an evolving platform for desiging, documenting and analysing buildings. It's core feature, a multi-dimensional, parametric model of a building project, is a quantum leap from its predecessor, Computer Aided Design. We have been using Autodesk's Revit as our primary BIM application since 2004. We provide here some insights into the advantages BIM has to the execution and maintenance of facilities.

A Short History of Drawings

An idea for constructing a building can be communicated in many ways. A simple voice instruction could work: "Make the house 24 x 32, shaped like a cape." One could whip out a napkin and a pen. These methods work when the building is simple enough to exist as a fully formed mental construct in the mind of the designer, and can be quickly communicated as such to the mind of the builder.

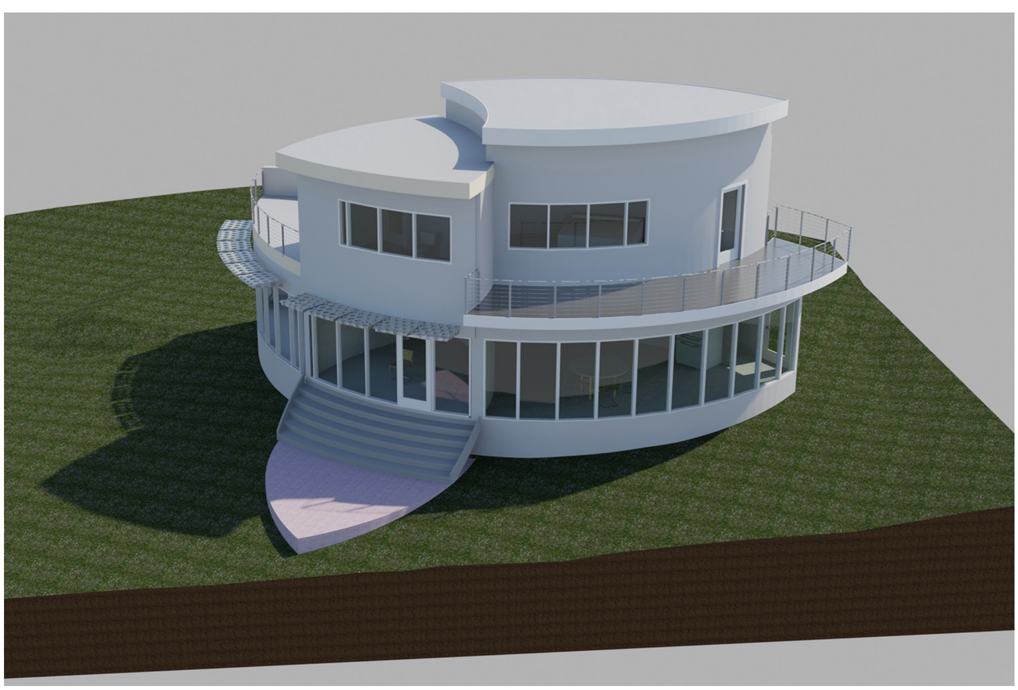
More complicated buildings require more effort to design, and more effort to communicate. Designers soon recognized drawings could become informative of themselves. By constructing a representation of a building plan, designers could use geometry to figure out dimensions and relationships. For instance, a well-constructed plan of a collonade can be used to measure the spacing between columns. The use of rigorous, or scaled hand drawings persists to this day.

When we were in graduate school in 1989-92, virtually all drawing was by hand. CAD was offered as a class, using a three-dimensional modeling program called GSDL. This program lacked a graphical user interface. The tediousness of writing code in text kept many from seeing the potential of computers as a design tool.

Commericial computer-aided design programs mimicked hand drawing. They were initially a change in media, not a change in platform. CAD programs were used to draw two-dimensional representations of buildings just as hand drawings were. CAD drawings brought increased rigor and accuracy. We used to say one could measure the distance between a line in San Francisco and a line in New York to the 64th of an inch using AutoCAD.

In 1995, we began working professionally with AutoCAD release 12. AcadR12 was a general purpose CAD program; there was nothing about it that made it appropriate for building design.

When AutoCAD was developed in the 1980s, there were expensive three-dimensional CAD programs in existence, but they worked on Unix mainframes. Autodesk brought CAD to the masses of design professionals, and made using CAD cost competitive to hand drawing. The economic advantage of CAD to hand drawing was in fact its decisive advantage. It took less hours to draw a building in CAD than it did by hand, even though the output was essentially the same. The economic value of



CAD came from the ability to use a create a component once and then use it over and over again. A building elevation drawn by hand might require one minute for each window. Drawing 20 of the exact same window would take 20 minutes. Changing those 20 windows to 20 smaller windows would take perhaps 30 more minutes: ten minutes to erase the windows and 20 more minutes to draw the new ones.

In CAD, the first window might take two minutes to draw and then turn into a re-usable component. That component could then be used to represent the other 19 windows, at a time cost of 5 seconds each. The time spent on all 20 windows would be about three and half minutes: two minutes for the first window and 95 seconds for the next 19. Changing all those windows might take another three minutes. Drawing 20 windows and then changing your mind on the window size was a 50-minute exercise in hand drawing. In AutoCAD, it took less than seven minutes.

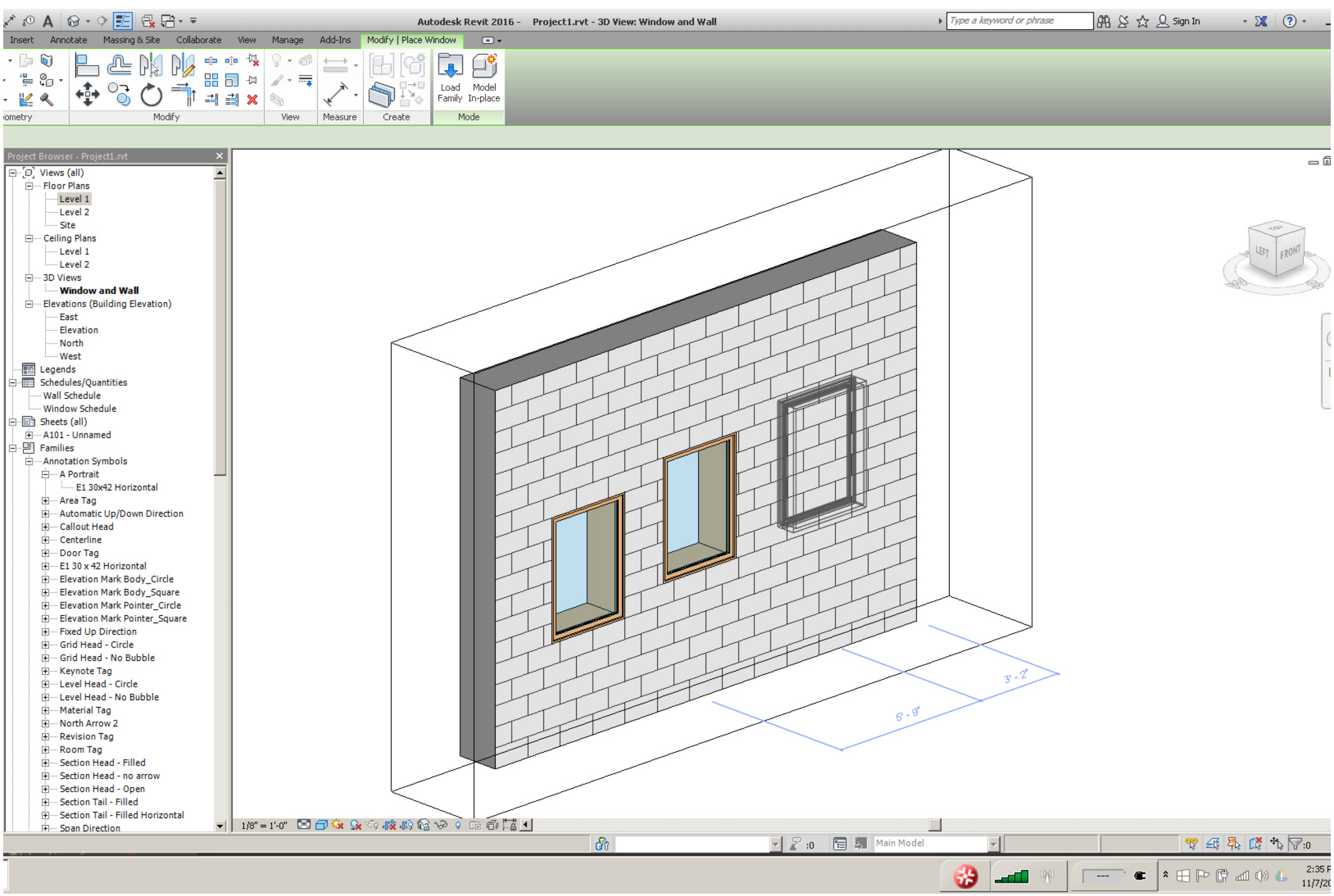
AutoCAD and other programs eventually did develop three-dimensional modeling capacity. There were early programs that were three-dimensional, but AutoCAD owned the building design market in the United States.

In the late 1990s, the two major alternatives to AutoCAD were Bentley and ArchiCAD. Both platforms offered what we now think of as BIM: the CAD file was a relational database with a graphical interface and output. Autodesk's offering was Architectural Desktop, built on its AutoCAD platform. This was an older platform with limited potential to become a true BIM platform.

The Model as Database

At some point in time, CAD program designers realized building components had relationships between each other, and that building components themselves came in many flavors. For instance, windows might be double-hung units or casements. Casement windows might be four feet tall or five feet tall. Five-foot tall casements might be single glazed or double glazed. Windows get put in walls, but they might be two feet from the left end, or three feet from the left end. They might be in masonry walls or in stud walls.

Organizing these parts, their relationships and their permutations could be done in a database: a multi-dimensional spreadsheet. Instead of providing a graphical



interface for users to construct window elevations out of static lines, provide a framework of variables that could receive user-provided values. A BIM window is a software object with a collection of variables such as height, width, and glass material. A designer who has placed 20 windows and decides to change their size can do so by changing the values provided to the size variables. This process mimics the process of setting up a spreadsheet to perform calculations based on user inputs. A BIM database is a spreadsheet with cells containing variables or equations. Somewhere in the spreadsheet is a cell whose content is “Window Height = X”. The user inputs the value for X, and this value gets reported to the cell containing the window itself.

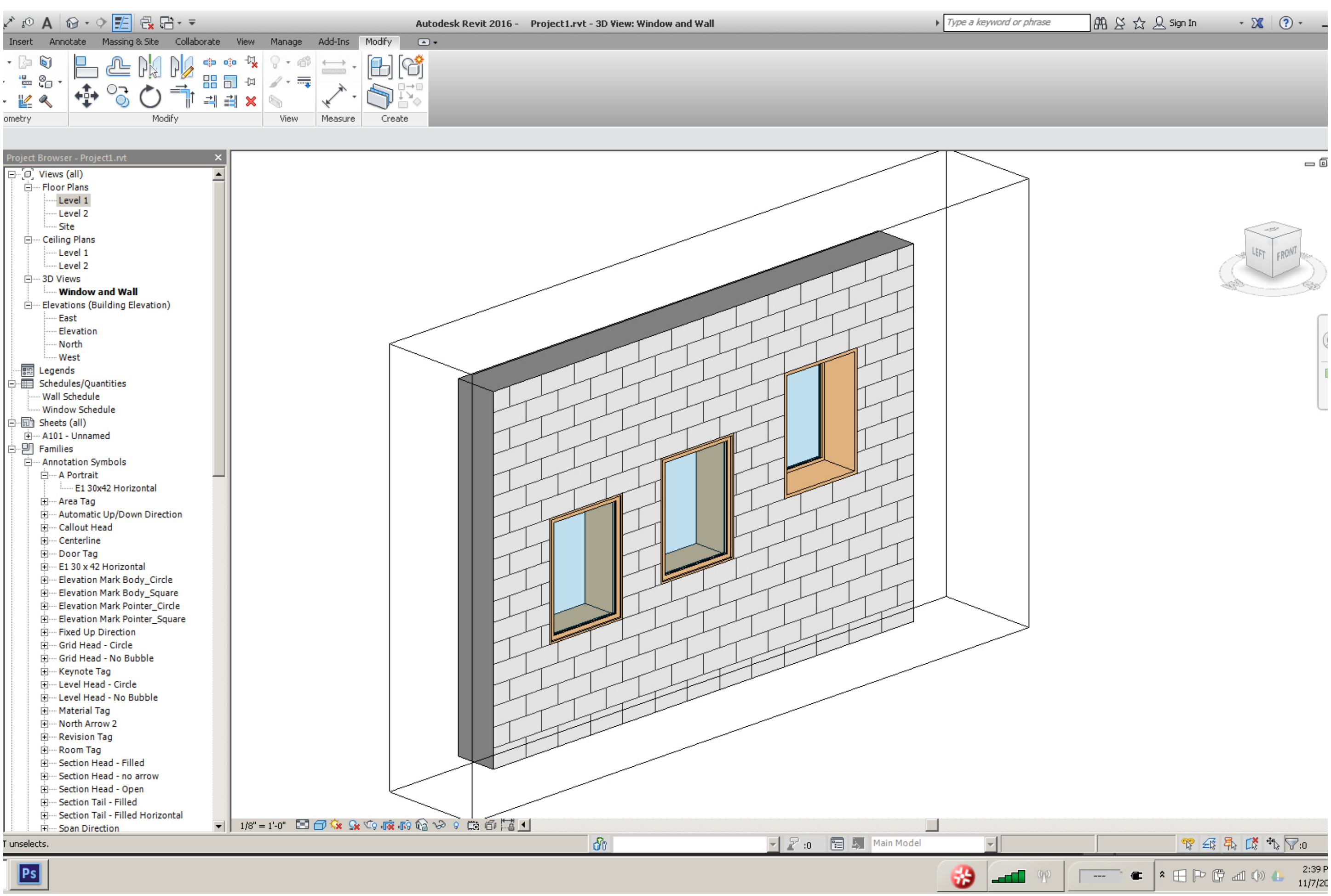
A BIM wall is also a collection of variables. It has a height, a length, and a volume. It can have variables that describe its function: Exterior, Interior, Structural. It can be made of one material or several materials. A wall can also relate to windows. A 10-foot by 10-foot wall has 100 square feet of area. However, if we place a 20-square foot window in that wall, the area drops down to 80 square feet. A BIM wall’s area is the result of it’s own dimensions minus the area of objects that displace some of its area.

The CAD Interface

We can visualize a wall with windows in several ways. There are the typical representations, such as plan and elevation, as well as sections. There are axonometric representations as well. In two-dimensional CAD, each view is a static representation of the hypothetical wall with windows. A designer hopes that a plan drawing reflects the design intent, and that the elevation and section drawings are coordinated with the plan and the design intent.

CAD drawings can be coordinated in the morning and lose that coordination by noon. A designer working in plan might move a window from the west side of an east-west wall to the east side. If that wall has been drawn in elevation, the elevation must be updated with the new window location. A wall section may have been cut through the window when it was on the west side, but not the east side.

The manual coordination of CAD drawings forced designers to draw as little as possible in the early stages of design in order to minimize effort. Why create elevations when the plan has not settled down? Why cut sections



that may need to be updated a dozen times? Labor-intensive drawings such as perspective or axonometric renderings are either always out of date, or just not done until the design has settled down. The drawings that can best communicate a design are the last to be produced.

The BIM Interface

The BIM output, or interface, is always coordinated because the designer is not actually drawing static lines that represent walls and windows. Rather, the designer is using a graphical interface to build a parametric database of interactive building components with software representations.

Let us break that last sentence into smaller chunks.

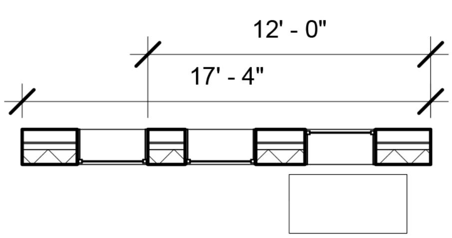
Revit uses a graphical user interface. This interface can be controlled to mimic plan representations, section/elevations, or three-dimensional representations. The interface is always looking at a volume of space where objects can be created. Depending on the type of object being created, the act of creating might involve a drag and drop, a series of clicks, or a click and a drag. What is being created is a software representation of a building component. Creating a component in a certain location using the GUI is in fact a process for defining that component in the relational database. If a designer creates a wall and a window in an axonometric view, the designer has not actually created an axonometric of a wall and window. The designer has simply used the axonometric as a particular visual space in order to place the wall and the window in the database. The BIM software is actually creating the axonometric by querying the database. The software sees the database contains a wall and a window in a certain configuration, and so then draws this configuration on the GUI.

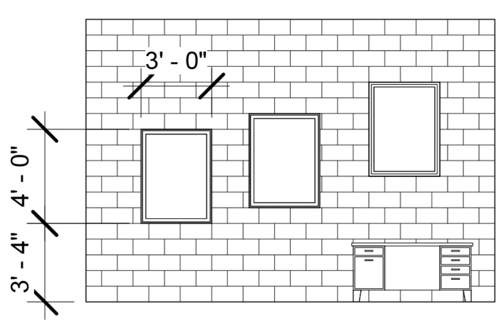
If the designer switches to a plan-oriented view, the wall and the window are displayed again, only in plan. If the the designer switches to an elevation or section view, the same software components in the database are displayed in elevation.

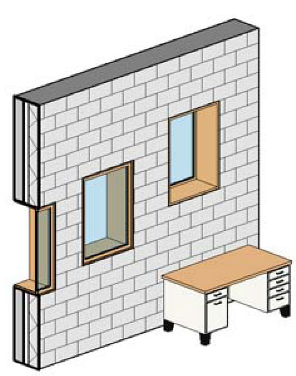
The designer can assemble a sheet of drawings that show the wall and window in plan, section, elevation and axonometric by setting up these corresponding views. A tabular representation can be made the same way. The architectural schedule, commonly used for doors and windows, can be created by displaying the database

Wall Schedule			
Area	Type	Volume	Length
172 SF	Type A	256.21 CF	17' - 4"

Window Schedule			
Type	Width	Height	Sill Height
36" x 48"	3' - 0"	4' - 0"	3' - 4"
36" x 48"	3' - 0"	4' - 0"	4' - 0"
36" x 48"	3' - 0"	4' - 0"	5' - 4"







information in tabular form. While not used frequently in CAD drawings, a wall schedule can be created just as easily as a window schedule. The schedules can display virtually any variable associated with the object type. Wall schedules can contain length fields. Window schedules can contain height and width fields.

Software Objects

CAD drawing is drawing lines that represent things, such as doors and walls. CAD standards developed a system for differentiating one line from another. AutoCAD used Layers to do this differentiation. One line might be drawn on a Wall layer, while another line might be drawn on a Door layer. A designer working in AutoCAD could select which layers were visible in a particular view. Thus, one could create a drawing (A two-dimensional collection of lines) with doors, walls, windows and furniture, and then selectively hide the lines that represented furniture. One could mistakenly draw furniture using Wall Layer lines. This does not make walls that look like furniture. It makes those Wall Layer lines stay visible when the Furniture Layer is turned off.

BIM furniture is not prone to this error. A BIM furniture component is part of a class of components call Furniture. Walls are similarly members of a class of components calls Walls. Wall objects are unique in that they can host window and door objects. A furniture object does not interact with windows and doors.

As the designer adds objects to the database, the software keeps track of the objects and their unique parameter values. It always has the ability to display the full, or filtered, set of objects in whatever way makes sense to the designer.

BIM output can therefore include a schedule of windows with the quantity of windows in the project. This quantity is based on how many windows the designer put into the model, not on a manual count of windows by the designer. Likewise, carpeting can be scheduled, and include the area of each carpet.

The parametric efficiency of a BIM model extends to documentation. BIM models have sheets, which are formatting objects used to print information on paper or PDF. A designer might cut a section on a plan and place the section on page 12 of the drawing set. The section cut object on the plan knows the section is on page 12, and will display this information. If the section is moved to page 13, the section cut object will dynamically update to reference page 13.

Just as a spreadsheet is used to create mathematical relationships that dynamically update based on input changes, so does a BIM model dynamically update based on user input changes. Almost every aspect of the architecture design and documentation process benefits from dynamic updating.

Visualization

BIM therefore accelerates the standard architecture processes just as CAD accelerated those processes 30 years ago. What we realized in switching to BIM was that many tasks that were too time consuming to do in CAD can now be done in BIM. One huge area of improvement is in visualization.

As mentioned earlier, the static nature of hand and CAD drawings meant it was very easy to have a set of drawings lose their coordination with each other. A change to a plan necessitated update changes to elevations, sections and schedules. Designers made perspective renderings of their conceptual designs at great risk of quick obsolescence. A rendering done for a schematic design meeting with a client almost inevitably became obsolete by the end of that meeting.

BIM software's rendering capability is quite good. Photorealistic renderings can be made on a reasonably fast machine in an hour. The renderings are based on the same database as the drawing set; the are little more than a particular type of view. Rendering views update just as dynamically as plans, elevations and schedules. It is eminently possible, and commonplace, to produce dynamically updated renderings daily.

The benefits of improved visualization are significant. Clients often have trouble understanding orthogonal graphics. Providing several renderings at regular intervals for client consumption reduces uncertainty about the design on the client side, and this in turn instils client confidence in their designer.

Being a Good Modeler

We have found BIM platforms are a significant improvement over CAD platforms. This is true using two metrics: BIM's ability to do the same thing CAD can do, but better, and BIM's ability to do things CAD could not do, and do them adequately.

BIM as a one-to-one replacement for a CAD platform is better if for no other reason than the BIM software is generally more robust than CAD software. Software developed in the 1980s is like a car that uses a carburator. There are better ways to control air-gas mixtures. Newer platforms use newer software technology.

BIM platforms are also more responsive to their vertical markets. AutoCAD is a general purpose application. Mechanical designers use it. There is nothing about AutoCAD that tailors it to the architectural profession. BIM, on the other hand, is tailored to the design and construction of buildings.

In order to realize the advantage of BIM, a designer needs to shift gears. This can be difficult, and it can actually create work.

Let us remember that one attribute of a BIM model is that it is essentially a virtual model of the proposed building. All the components of the physical building get modeled. This is the only way to accurately produce window, door, wall, flooring or roofing schedules. If it's not in the model, it doesn't show up in the documentation.

What does this mean?

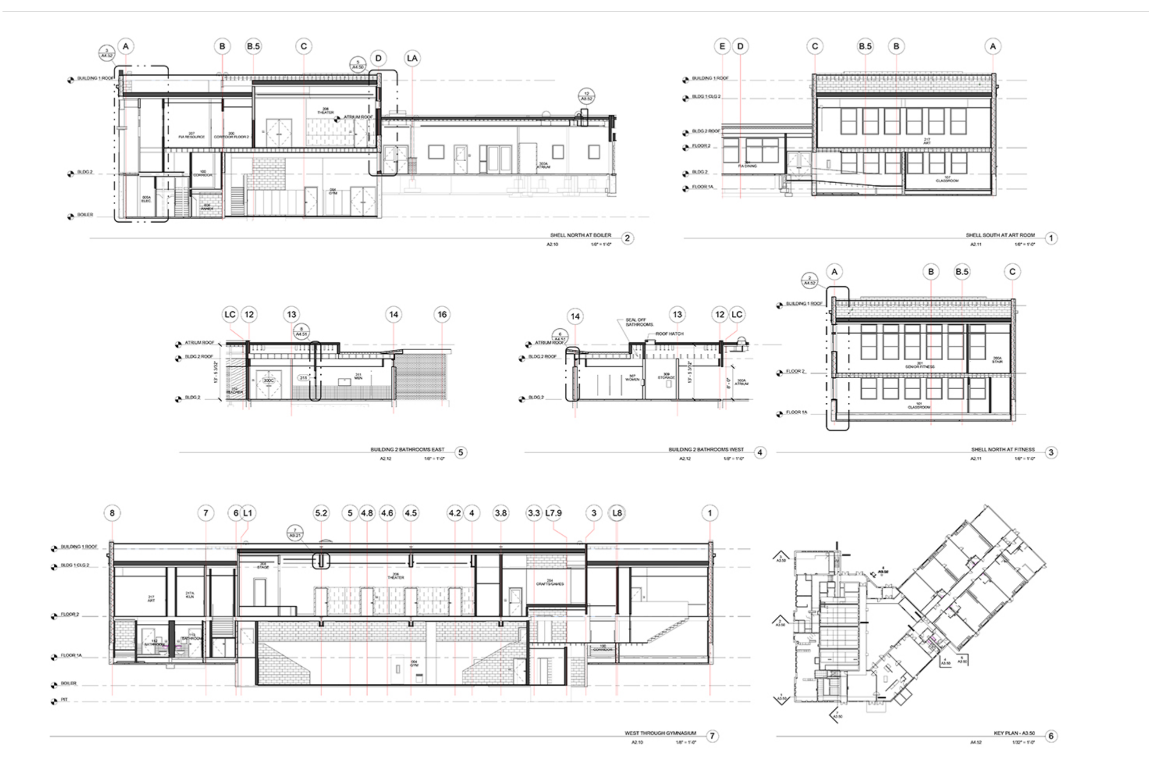
Let's say that a project requires fire extinguishers in quantities that comply with the NFPA 101. In the old days, one could simply place a note on a drawing or in a specification that says no part of the building shall be more than 75 feet away from a fire extinguisher. This performance specification is good, but it does not explicitly indicate where those extinguishers should go, or where exactly in the building they should be located.

In a good BIM model, we will be forced to show exactly where those extinguisher are. The BIM model should be able to show exactly how many extinguishers are required for the project, in their exact location.

Data Presentation

Designing using BIM is a two-part process: constructing the model, and then presenting information to consumers. A model is a software construct, so consumers who cannot open the software model directly depend on the publishing efforts of the design team. The publication may be a set of paper drawings, or a PDF, or even a three-dimensional extraction using .dwf or another format. All these publication methods involve dumbing down an information-rich model. For instance, a door in a BIM model is an entity loaded with information: size, hardware group, color, panel type, frame type, and so on. When a model is published onto sheets, none of that information comes through. The recipient is left with the equivalent of a CAD drawing: lines that look like a door, but nothing else to indicate the qualities of that door.

Designers must annotate their model to display this information. A door schedule can be used to display door



quality information. BIM programs also contain a vast array of annotation objects that do nothing more than extract data from the BIM object to display it with text. Wall tags, door tags, window tags, casework tags: These are all special annotation objects that dynamically display information contained in the BIM object. A designer does not manually write a string of text to indicate a wall's type. That text string is part of the wall's attributes, which then gets displayed by the tag.

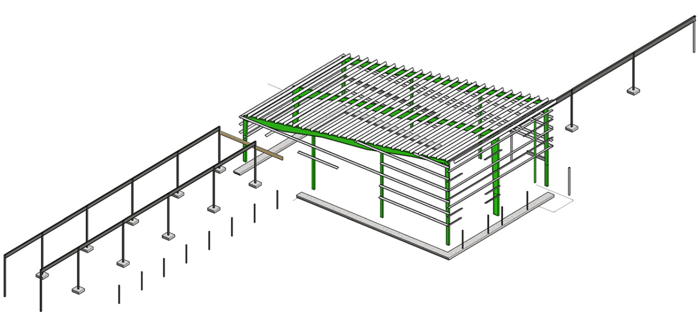
We have developed dynamic identifier markers for practically every BIM component we use. This has streamlined the annotation process, and ensures consistency in annotation. For instance, dynamic tagging prevents one door frame being tagged "HM DOOR, PTD" while the same door used somewhere else is being tagged "PTD HM DOOR".

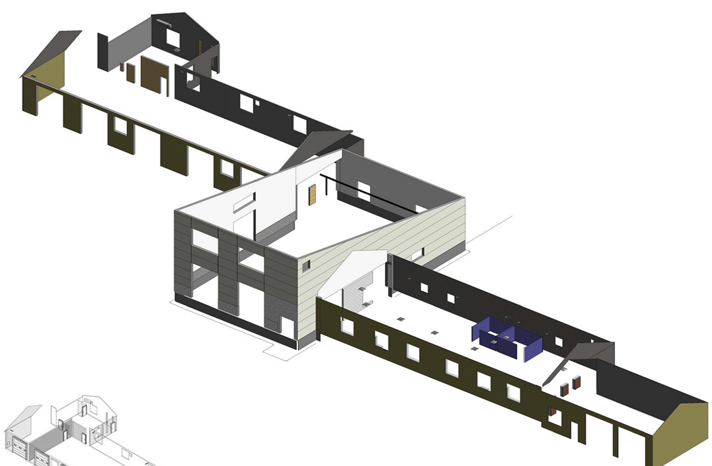
BIM and Virtual Construction

The generation of accurate schedules and sections depends on accurate and complete modeling of the project. In a CAD drawing set, the plans are almost certainly accurate and fully developed. Every door in the project is shown in plan. Every wall is shown in plan. Most likely every window is shown in plan, though this may not be the case. Transom windows may be shown in elevation and not in plan.

CAD and BIM both allow the use of tropes, or shortcuts for documentation. A text note may point to a wall and indicate the wall has a wainscot. An even simpler trope would be a text note that simply says "Wainscot in classrooms, typ." This may be a fairly clear and unambiguous specification, but it requires some work on the part of an estimator or contractor to determine how much wainscot is really involved. A fully developed BIM model will show this wainscot in elevation and section, and can also schedule the wainscot, with area or length results. A partially developed BIM model that relies on CAD tropes is a legitimate document. Designers must determine what level of BIM development is appropriate to communicate the design.

For many BIM designers, a fully developed model is an appropriate standard to attain. When this is achieved, the model really is a virtual version of the building. Theoretically, every possible conflict is visible and can be addressed. Special situations where the wainscot is in potential conflict with other building components may occur, and can be resolved. Every component that requires cost estimating is quantified dynamically by the software. Nobody needs to wonder if there are five or six





DOORS C

MARK	TO ROOM	Type Mark	THICKNESS	COMMENTS	Type Comments	Function
C2		HID-F0-3087	1 1/2"	Wing C		Exterior
C3		HID-F0-3087	1 1/2"	Wing C		Exterior
C4		HD-F110	1 3/4"	Wing C		Exterior
C5		HID-F0-3087	1 1/2"	Wing C		Exterior
C6		HID-F0-3087	1 1/2"	Wing C		Exterior
C7		HID-F0-3087	1 1/2"	Wing C		Exterior
Exterior: 6						
C8	102	HID-F0-3089	1 3/4"	Wing C		Interior
C9	103	HD-F58	1 3/4"	Wing C		Interior
C10	102	HID-F0-3070	1 3/4"	Wing C		Interior
Interior: 3						

DOORS D

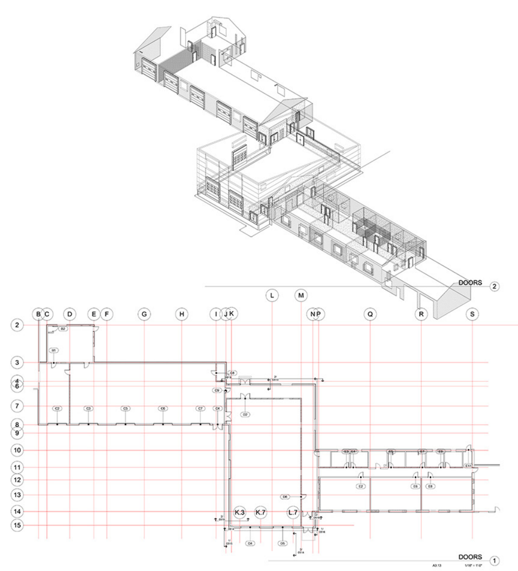
MARK	TO ROOM	Type Mark	THICKNESS	COMMENTS	Type Comments	Function
D1		HD-F110	1 3/4"	Wing D		Exterior
D3	104	HD-F36	2"	Wing D		Exterior
D4	104	HD-F36	2"	Wing D		Exterior
D5		HD-F36	2"	Wing D		Exterior
D7		HD-F110	1 3/4"			Exterior
Exterior: 5						
D2	103	HID-F0-3090	1 3/4"	Wing D		Interior
D6	105	HID-F0-3081	1 3/4"	Wing D		Interior
D8	104	HID-F0-3089	1 3/4"	Wing D		Interior
D12	103	HID-F0-3089	1 3/4"			Interior
D13	102	HD-F74	1 3/4"			Interior
Interior: 5						

DOORS E

MARK	TO ROOM	Type Mark	THICKNESS	Type Comments	Function
E11		HD-F105	1 3/4"		Exterior
Exterior: 1					
E8	107	HID-F0-3089	1 3/4"		Interior
E6	107	HID-F0-3089	1 3/4"		Interior
E2	107	HID-F0-3089	1 3/4"		Interior
E10	120	HID-F0-3089	1 3/4"		Interior
E9	118	HID-F0-3089	1 3/4"		Interior
E7	116	HID-F0-3089	1 3/4"		Interior
E5	114	HID-F0-3089	1 3/4"		Interior
E4	110	HID-F0-3089	1 3/4"		Interior
E3	108	HID-F0-3089	1 3/4"		Interior
E12	21	HID-F0-3089	1 3/4"		Interior
Interior: 10					

DOORS B

MARK	TO ROOM	Type Mark	THICKNESS	Type Comments	Function
B1	101	HID-F0-3070	1 3/4"		Interior
B2	101	HID-F0-3070	1 3/4"		Interior
B3	102	HID-F0-3070	1 3/4"		Interior
B4		HD-F105	1 3/4"		Exterior



fire extinguishers, and everybody can see that one fire extinguisher cabinet partially overlaps the wainscoting.

Building Analysis

For decades, structural and energy analysis have been performed using computers. The software tended to be difficult to use. EnergyPlus, for instance, is a text-based program that requires a designer to describe the building using text to describe cartesian coordinates for building surfaces.

With BIM models essentially being descriptions of building geometry that can have parameters, it did not take too long for software companies to realize BIM models could be the input for analysis engines.

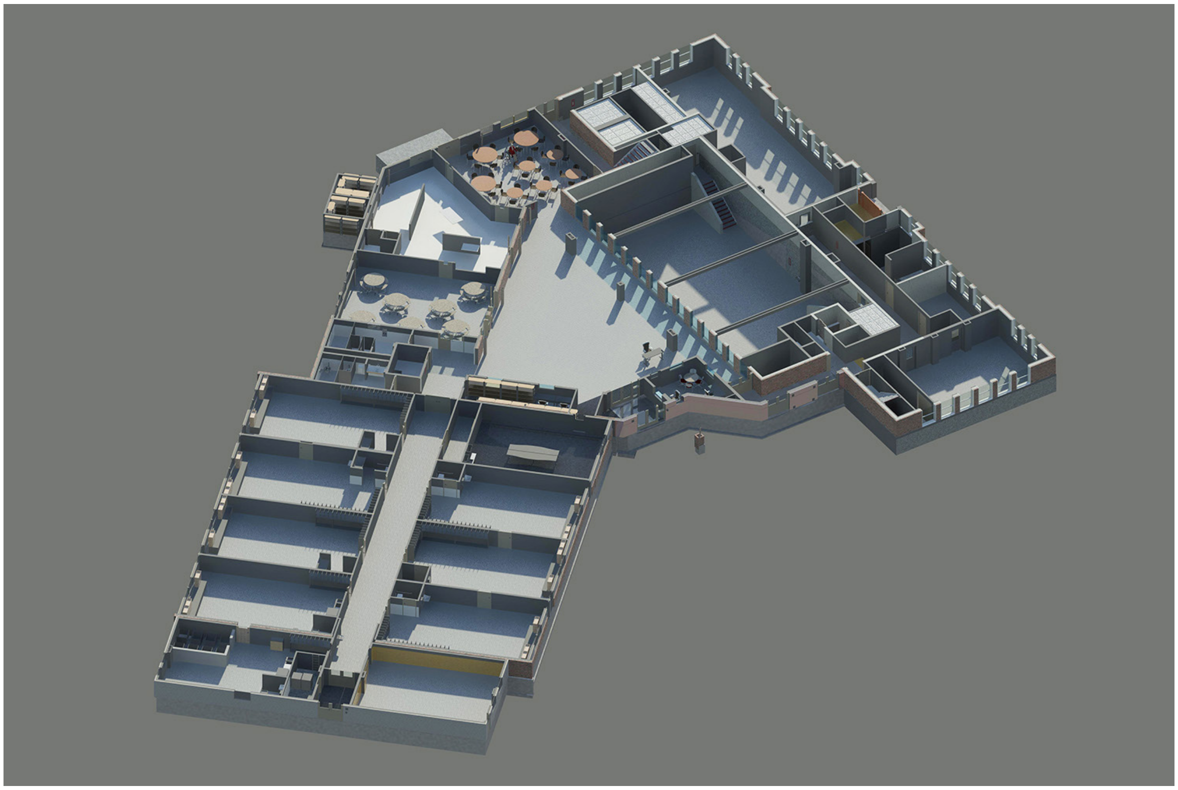
At this point in time, BIM energy analysis is a fairly mature process. A BIM model can be converted to a form readable by analysis engines, including thermal properties of components like walls, doors and windows. Mechanical systems in a BIM model can likewise be converted to readable form. Revit and third-party software have essentially reached the “push of a button” level of ease for energy analysis. This is a huge step forward in bringing dynamic feedback about a design’s energy use to the designer. What used to cost $10,000 per analysis iteration can be done for tens of dollars per iteration.

BIM and Responsibility

Relying on the BIM model to be an accurate depiction of the entire building potentially shifts new responsibility to designers, and therefore potentially shifts new liability to designers. Should a designer provide any signal about building quantity to a contractor? Or, should a designer place all responsibility for building quantity on the contractor?

Even when the software could not automate quantity calculations, designers still provided them, within limits. Door schedules have always purported to be an exhaustive list of all doors in the project. Why would a carpet schedule be different?

Designers are rightfully nervous about contractors who may end up making no effort to verify quantities. The industry currently has quite a lot of redundant effort built into projects. Shop drawings are elaborations of design drawings. In effect, a shop drawing is the product of a designer producing a drawing, and then asking a fabricator to produce their version of the drawing, and submit it for the designer to review. In the meantime, the general contractor is reviewing both the design drawings and the shop drawings.



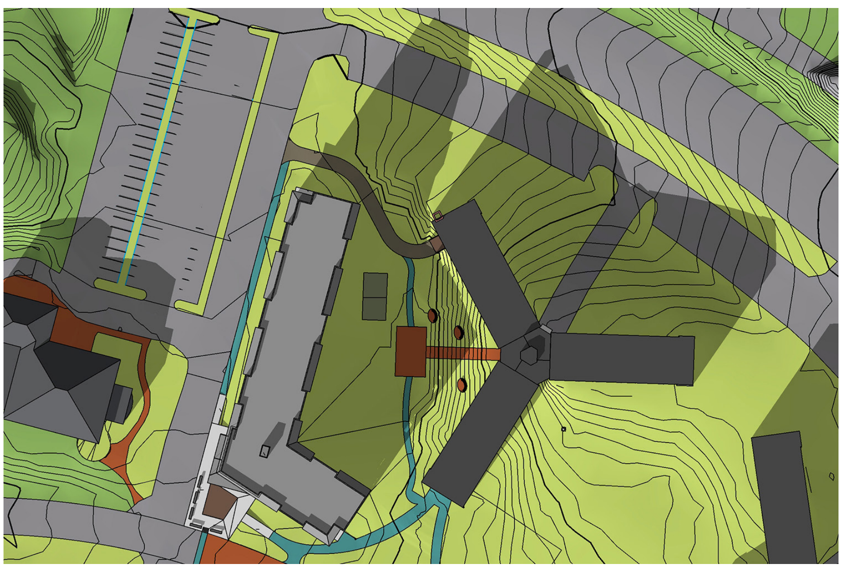
Efforts to remove redundancy in the construction process in order to achieve economy are short-sighted. Even with BIM, the industry benefits from redundant reviews. BIM offers an opportunity to increase the review of quantities by allowing the designer to make an initial statement about quantity on the design she is doing.

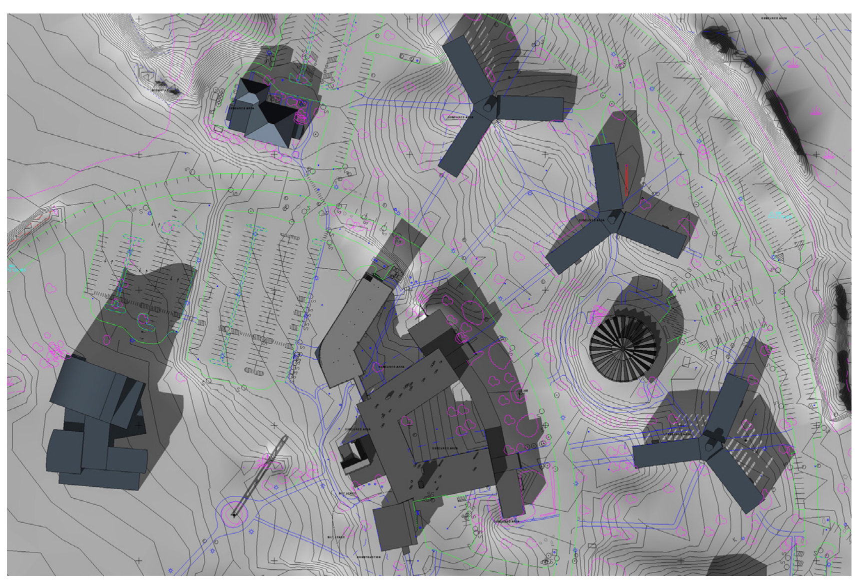
Sharing the Model

We have found ourselves building rich BIM models replete with quantity schedules, but lacking an audience that can use them. Three major groups can benefit from an architect's BIM model: consulting engineers, contractors, and owners. Model sharing among consultants is commonplace. We do not hear many gripes about "who owns the model?" and "What if my consultant changes my model?" Consultants work together because the trust each other, including with each other's BIM output.

Sharing models with contractors may seem sketchier than sharing with consultants, especially since designers enter into shot-gun marriages with contractors, particularly on competitively bid projects. At this point there are so few contractors with BIM capabilities, and even fewer contractor who use whatever capability they have, that the question of designer-contractor model sharing is moot. We have provided our model to one contractor for bidding, but they did not submit a bid.

A myriad benefits can accrue for contractors who can use a BIM model. We are simply waiting for those contractors to show up.





BIM and Contractors

Benefits for contractors who can extract information from a BIM model include:

Being able to publish trade-specific drawings without having to rely on the designer. The designer has built the model. If the contractor needs to extract information on just Division 10 specialties to give to a subcontractor, he can.

Being able to see areas of the model that have not been specifically documented. When designers cut sections, they do so in order to cover as many situations as possible. This does not mean every part of every wall has been cut with a section. A contractor could very well be interested in a particular area of the model that the designer did not think was interesting.

Being able to get dimensions not shown on the set. Designers also provide as many dimensions as possible, although some old-school designers think the fewer the dimensions, the less chance for a conflict. Beyond the fact that it is impossible to have conflicting dimensions in a BIM model, designers obviously do not provide dimensions betwee every pair of parallel surfaces. There are always places where a contractor needs a dimension not shown on the drawings.

BIM and Facilities Management

Why should facilities personnel be excited about BIM?

First, projects designed with BIM tend to be more responsive to client needs. It is easier to make changes to a project during design with BIM than with CAD, which means the fluid design process can stay fluid longer. A program change made during construction documents is much easier to handle with BIM than with CAD. The three-dimensional nature of BIM drawings also gives users and other stakeholders a clearer understanding of the project. They see the project in three dimensions as it is being designed, so they understand the design better.

Second, BIM projects are less prone to drafting and coordination errors.

Third, BIM models are a very convenient way to graphically store a lot of facilities information. When were those ceilng tiles installed? What type of lamp do those fixtures use? What is the brand and type of that carpet? Buildings are three-dimensional objects that are constantly changing. What better way to track the life of a building than with a dynamic, graphic, relational database?

Conclusion

We have been designing buildings in BIM exclusively since 2004. We do so because we can be more cost effective while delivering coordinated drawings that are responsive to client needs. We are sure clients and contractors will also benefit by adopting BIM.

Sealander Architects hopes this article has proved helpful.

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Maine Licensed Architect