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White Paper

Building Information Modeling

Introduction

Building information modeling is Autodesk's strategy for the application of information technology to the building industry. Building information modeling solutions have three characteristics:

(1) They create and operate on *digital databases* for collaboration.

(2) They *manage change* throughout those databases so that a change to any part of the database is coordinated in all other parts.

(3) They capture and preserve *information for reuse* by additional industry-specific applications.

The application of building information modeling solutions results in *higher quality* work, *greater speed* and productivity, and *lower costs* for building industry professionals in the design, construction, and operation of buildings.

This paper discusses how the use of information technology in the industry has led to the idea of building information modeling and the characteristics and benefits of building information modeling solutions.

The Road to Building Information Modeling

In the early 1980s architects began using PC-based CAD. The familiar layer metaphor that originated with pin-bar drafting was easily adapted to the layer-based CAD systems of the day, and within a few years a large percentage of construction documents and shop drawings were plotted from computers rather than being manually drafted on drawing boards.

Slowly technology began to affect the process. DWG files were exchanged with consultants instead of physical underlay drawings. Beyond simple graphics these files communicated information about a building through their layer structure; a rectangle on one layer represented a concrete column, but on another layer a tile pattern on the floor. Electronic file formats originally designed to store only graphics and drive plotters now directly conveyed information about the building that would not appear in the plotted version of the file. The use of CAD files was evolving toward communicating information about a building in ways that a plotted drawing could not.

This evolution continued with the introduction of object-oriented CAD in the early 1990s. Data "objects" in these systems—doors, walls, windows, roofs—stored nongraphical data about a building in a logical structure together with the building graphics. These systems often supported geometrical modeling of the building in three dimensions, thereby automating many of the laborious drafting tasks like laying out building section drawings and generating schedules. Forward-thinking design firms adopted these tools, realizing that the data in the object-oriented CAD files, if carefully structured and managed, could be used to automate certain documentation tasks like schedules and room numbering.

A parallel development in the 1990s was the increasing use of the Internet for sharing data digitally. Suddenly information could not be effectively communicated unless it was represented digitally. CAD files that had been exchanged on floppy disks within the design team appeared instead on Internet FTP sites, on web pages, and attached to emails. The same forward-thinking design firms who were adopting object-oriented CAD into their practices began sharing and delivering their documents to clients digitally and began investigating web-based project management and collaboration services.

But object-oriented CAD systems remain rooted to building graphics, built on graphics-based CAD foundations, and as a result are not fully optimized for creating and managing information about a building. Other industries, such as Manufacturing, have realized great benefit from nongraphical, parametric information technology tools. Another generation of software solutions, designed with current technology and purpose-built, is required to fully realize the benefits information technology can bring to the building industry. This next generation of information-centric software provides *building information modeling* in place of building graphic modeling.

By storing and managing building information as databases, building information modeling solutions can capture, manage, and present data in ways that are appropriate for the building team member using that data. Because the information is stored as a database, changes in that data that so frequently occur during design can be logically propagated and managed by the software throughout the project life cycle.

Building information modeling solutions add the management of relationships between building components beyond the object-level information in object-oriented CAD solutions. This allows information about design intent to be captured in the design process. The building information model contains not only a list of building components and locations but also the relationships that are intended between those objects. For example, that a door should be 3 feet from a window or the eaves of the roof should overhang the exterior wall by 550 mm. Or that three beams should be spaced equally across a structural bay or that the slope of an excavation should be maintained at a certain angle. These relationships, implicitly understood by the designer, become explicit when the building is described in a building information modeler.

Further, these relationships can be inferred by the building information modeler as the user works, or explicitly entered as work progresses. These relationships then allow for changes to the building information model to be managed by the software consistent with the design principles and intent for the project. The richness of the relationships embedded within building components themselves, as well as those embedded in the overall model, makes reuse of the data in other applications even more powerful and the design process significantly more efficient.

The Characteristics of Building Information Modeling

Building information modeling solutions create and operate on *digital databases* for collaboration, *manage change* throughout those databases so that a change to any part of the database is coordinated in all other parts, and capture and preserve *information for reuse* by additional industry-specific applications.

Digital Databases

Building information modeling solutions create and operate on digital databases for collaboration. The building industry has traditionally illustrated building projects through drawings and added information over those illustrations via notes and specifications. CAD technology automated that process, and object-oriented CAD extended the idea of adding information to illustrations and graphics into software. The result of earlier manual drafting, graphics CAD systems, and object-oriented CAD systems were identical: the creation of graphic abstractions of the intended building design.

The principles of building information modeling turn this relationship around. Building information modeling applications *start* with the idea of capturing and managing information about the building, and then present that information back as conventional illustrations or in any other appropriate way. A building information model captures building information at the moment of creation, stores and manages it in a building information database, and makes it available for use and reuse at every other point in the project. Drawings become a view into the database that describes the building itself.

In a building information modeler, the building information is stored in a database instead of in a format (such as a drawing file or spreadsheet) predicated on a presentation format. The building information modeler then presents information from the database for editing and review in presentation formats that are appropriate and customary for the particular user. Architects, for example, work on the information using the conventions of the highly stylized symbolic graphic language of building design (such as plan, section, and elevation), entering and reviewing information in a format that looks just like the architectural drawings they have worked with for years. They work on the building information *through* a drawing rather than working directly on a drawing in the computer. Similarly, structural engineers work with the data presented graphically in familiar framing and bracing diagrams, quite different from the architects' interface to the data. Builders work with some of these same presentations and also isometric views of the building geometry to study phasing and coordination issues and databases or spreadsheets of quantity data provided from the building information model.

Although each professional working on the building project views the building information in the way he or she expect to see it, these presentations of the information—drawings, schedules, cost estimates, other conventional presentations of the building information—are all views into the same information model. While each discipline interacts with familiar and customary views of the information, the building information modeler assures that changes made in any of these views is reflected in all other presentations.

Building information models organize collaboration by the building team through digital databases. The building information model can be distributed to individual team members working on a network or sharing files through project collaboration tools such as the Autodesk® Buzzsaw™ service. Team members work independently on local data sets while the building information modeling solution manages changes to the model from each of these local databases in a central shared location. Team members can compare their work to concurrent work by other team members and dynamically reserve and release portions of the database for use over the network. A record of these interactions—who changed what, and when—is available for review, and a history of all changes made by all team members can be preserved in the building information model for as long as this information is useful. Changes can be selectively rolled back to support investigations of options or changes in design direction.

Change Management

Building information modeling solutions manage iterative change through a building's design, construction, and operation. A change to any part of the database is coordinated in all other parts.

The process of building design and documentation is iterative. The understanding of a design problem develops during the design process. In addition to the refinements typical to any design process, a new insight into the design problem may lead the design team to discover that the solution could be quite different, and possibly better. At that point another iteration occurs that may reconsider earlier assumptions. Managing this iterative change is an inherent part of the design process. Technology tools and work processes that do not allow the design to be refined and reconsidered in an iterative way as the project develops discourage the best possible solutions to the design problem. Building information modeling solutions, because of the management of relationships within the data and change to that data, are ideal for this approach. And using building information modeling tools results in the highest quality project for the owner and the best possible work by the team.

Maintaining an internally consistent representation of the building as a database improves drawing coordination and reduces errors in the documents to the benefit of all building team members. Time that would otherwise be spent in manual document checking and coordination can be invested instead in the real work of making the building project better. The resulting documents are of higher quality, and thus the costs of changes and coordination are reduced. Building information modeling tools enable the design, construction, and occupancy of the building to proceed with less friction and fewer difficulties than conventional tools.

Estimating, procurement, and construction are also iterative processes of definition and elaboration. Specific materials and products are selected from among the range of possibilities that meet the project specification. Selection, refinements, and substitutions may result in changes to some aspects of the design. Ambiguities in the design documents are resolved between the design and construction teams before construction. The construction and design teams consider changes to improve constructability and value for the client. Each of these decisions requires evaluation and that new information be captured to support later evaluations as well as operation and management of the building. Building information modeling solutions capture and manage this information and make it available to support the collaborative process.

The operation of buildings after completion is also an iterative process that is well supported by building information modeling solutions. The first occupancy of a building—the end of the conventional design and construction cycle—is just the beginning of the life and use of the structure. The evolving occupancy of the building together with the maintenance requirements of the building materials, assemblies, and systems result in changes throughout the life of the building. Building information modeling supports the building life cycle with solutions for the design and documentation of the continuing maintenance, renovation, and renewal of the building itself within the building information model. For example, information about all the successive renovations to a building can be maintained in the building information model, forming a record of all changes that have been made to the building in its history.

Reuse of Information

Building information modeling solutions capture and preserve *information for reuse* by additional industry-specific applications. Successful information technology solutions outside the building industry are based on one primary principle: Data is captured once, as close to its point of origin as possible, and stored in a way that it is always easily available and can be presented in context whenever required. A simple example is a personal financial management package that captures information from your checkbook register as you write checks and make deposits, stores and manages that information for a variety of purposes, and presents it back as your income tax return in one case and a statement of net worth in another. Building information modeling accomplishes the same thing for the building industry.

The moment that an architect sketches the outline of a building on a site survey, data is created. The general size of the building footprint is now known. General program requirements and planning ratios can be applied to deduce the overall building configuration. Similarly, when an architect is working out the building plan, data is being created that can be re-presented in interior elevations, sections, and schedules. Conventional tools require all this data to be rederived at the point in the project where the information about building size or sections and schedules is required. Building information modeling tools capture this data at the moment it is created, store it, and make it available for re-presentation as information in other documents and artifacts as needed.

A construction cost estimator traces over a drawing on a digitizing tablet to derive quantities for a cost estimate or bid or to measure that drawing manually. The construction project manager in the same company traces over these same drawings to develop plans for construction sequencing and phasing. Using building information modeling, instead of tracing over the plans for the quantities, the estimator and the design team can interact with the building information model. Or, if the project team is not ready for that level of collaboration, the estimator can trace over digital plans in software, constructing a building information model in about the same amount of time required for the manual tracing. Now this data is captured in the building information model itself and can be re-presented as a phasing and sequencing plan. A design-build firm, in which the building information model can be easily shared between design and construction professionals, can realize even greater benefits.

A third example is the use of schedule data in a building information model for inventory management in a retail operation. As the display unit layout is planned for a store in a building information model, the possible configurations and capacity for each unit are captured and reported back later in a schedule for inventory calculations, and the inventory schedule information can be linked to a procurement system to coordinate the management of inventory with the capacity of the store. The building information model data extends to the support of the store operations.

Reuse of building information leads to connections from Autodesk’s current solutions to other applications for energy analysis, structural analysis, cost reporting, facility management, and many others. The persistence of the building information model through the building design, procurement, construction, and operation supports the management of workflow and process around this information.

The Benefits of Building Information Modeling

The application of building information modeling solutions results in *higher quality* work, *greater speed* and productivity, and *lower costs* for building industry professionals in the design, construction, and operation of buildings.

Higher Quality

Building information modeling solutions allow exploration and changes to the project at any time in the design or documentation process without encumbering the design team with laborious recoordination tasks. They also return more time for design and solving real architectural problems to the design team by minimizing coordination time and manual checking. By sharing common building information modeling tools, more experienced team members work together concurrently with the production members of the project team through all phases of the project, providing close control over technical and detailed decisions about the execution of the design. In construction the consequences of proposed or procured products can be studied and understood easily. The builder can quickly and easily prepare plans showing site utilization or renovation phasing for the owner, communicating and minimizing the impact of construction operations on the owner's operations and personnel. The building owner uses building information models to improve quality in the management of the building. The building information model provides a digital record of building renovations and improves move planning and management.

Greater Speed

With building information modeling solutions the design and documentation of the building can be done concurrently instead of serially. Design thinking is captured at the point of creation and embedded in the documentation as the work proceeds. All deliverables for the design team—schedules, color-filled diagrams, drawings—are created dynamically while the design work is being done. When a change is made, all the consequences of that change are automatically coordinated through the project. All of this allows the design team to deliver better work faster. The production of key project deliverables, like visualizations and regulatory approval documents, requires less time and effort by the design team, so the project can move ahead faster. In construction the builder can use the building information model (or create one) to accelerate the quantification of the building for estimating and value engineering purposes. This same model is then reused for revised estimates and construction planning. Building information modeling accelerates the adaptation of standard building prototypes to site conditions for businesses such as retail that require similar buildings in many different locations.

Lower Cost

Using building information modeling, design teams get more work done with fewer people. A smaller design team means lower costs and less chance for miscommunication. Because the documents are coordinated by the computer and therefore can be more complete, the cost of changes and coordination in construction administration is reduced.

Floor area-based (square-foot) budgeting and cost estimating are easier with a building information model, and cost information is available earlier and can be updated more frequently than with conventional tools. Changes late in the design process to reduce construction costs are difficult, inefficient, and expensive for the design team. With better cost information available from a building information model these kinds of changes are less likely.

In construction, less time and money are spent in process and administration because document quality is higher and construction planning is better. More of the owner's construction dollar goes into the building instead of administration and overhead in design and construction. The building information model is also used to access and manage physical information about the building such as finishes, tenant or department assignments, and furniture and equipment inventory, as well as financially important data regarding leasable areas and rental income or departmental cost allocations. Access to this information improves both revenue and cost management in the operation of the building.

Conclusion: Better Building Projects

Building information modeling solutions create and operate on *digital databases* for collaboration, *manage change* throughout those databases so that a change to any part of the database is coordinated in all other parts, and capture and preserve *information for reuse* by additional industry-specific applications. Through the application of information technology to the problem of describing a building in software, they enable *higher quality* work, *greater speed*, and improved *cost effectiveness* for the design, construction, and operation of buildings.

What all of us in the building industry are working toward is the building; that is our accomplishment and the value delivered. Every bit of time and effort in the process that goes into something not manifested in the building itself is energy wasted; energy dissipated as heat from friction instead of energy used to make the building better. The time spent coordinating the documents isn't improving the architect's real work nor making the building any better—it's just making the drawing set better. Time spent transferring a pile of dirt from one part of the site to another to get it out of the way of the concrete trucks doesn't make the building any better. Building information modeling solutions allow more of the building team's effort to go into the result rather than the process.

Thank you for your interest in Autodesk solutions for the building industry. If you have any questions about this paper or are interested in further information about building information modeling solutions from Autodesk please contact us at http://www.autodesk.com/buildinginformation.

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