

# Parametric Building Modeling: BIM's Foundation

This paper presents a brief explanation of parametric building modeling, providing several tests you can apply to determine if a BIM solution is using a true parametric building modeler (as characterized below), and exploring why parametric building modeling is so critical for BIM.

## What is Parametric Modeling?

Original CAD engines used explicit, coordinate-based geometry to create graphic entities. Editing these "dumb graphics" was cumbersome and extremely error prone. Documentation was created by extracting coordinates from the model and generating standalone 2D drawings. As graphic engines matured, graphical entities were combined to represent a design element (a wall, a hole, etc.). Depending on the software, the models became "smarter" and were a bit easier to edit. Surface and solid modelers added more intelligence to the elements and enabled the creation of complex forms.

But the result was still an explicit (coordinate-based) geometric model, which was inherently difficult to edit and had a tenuous relationship to extracted drawings that easily fell out of synch with the model.

Then came parametric modeling engines that used parameters (numbers or characteristics) to determine the behavior of a graphical entity and define relationships between model components. For example, "the diameter of this hole is 1 inch" or "the center of this hole is midway between these edges." This meant that the design criteria or intent could be captured during the modeling process. Editing the model became much easier and preserved the original design intent.

This was the breakthrough that gave credibility to the concept of a digital design model. The mechanical design world (at the forefront of parametric modeling) made MCAD parametric modeling the status quo for mechanical design.

## What About Buildings?

Unfortunately, MCAD parametric modelers don't scale to a building project. They usually rely on two basic technologies to propagate change: history-based (which plays back the design steps for the model each time a change is made) or variational (which attempts to simultaneously solve all conditions with each change). Using these change engines to resolve even a small building is prohibitively slow.

MCAD modelers also generally require the user to embed a lot of constraints (i.e., relationships) so that the change technologies described above can recalculate the result.

These “fully constrained” models are suitable for the mechanical design world because the product (manufactured from raw chunks of material) has to be precisely defined - unlike a building, which is generally a collection of prefabricated components with relatively few constraints that really matter to a building designer.

The technology that made parametric modeling work for building design, and therefore enabled parametric building modeling, is the context-driven change engine used in Revit® platform for building information modeling.

### Purpose-Built for Building Design

Revit uses a context-driven change engine to update a partially constrained model - creating a network of building element relationships (inferred by the software and/or set by the user). It then uses this network to help resolve changes later. When you sketch or place components, Revit retains inter-element relationships, but there is no particular order to these relationships. Subsequently, as you modify one element, the parametric change engine determines which other elements need to be updated and how to make the change.

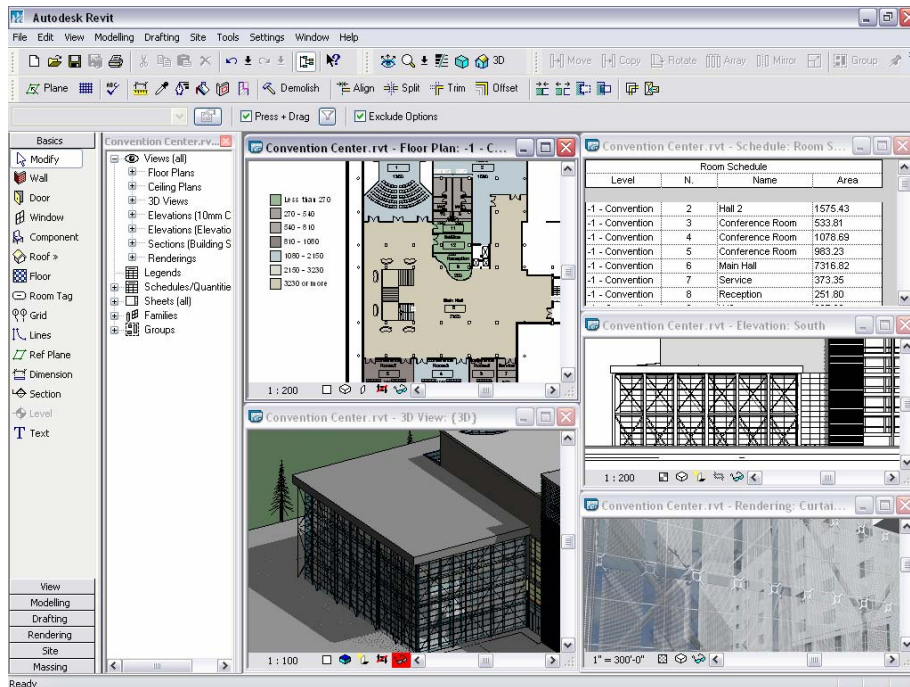


Figure 1

With state-of-the-art parametric building modeling, BIM software can coordinate a change made anywhere, including on sheets ready to plot, everywhere it matters: in 3D views and drawing sheets, schedules and elevations, sections and plans.

The approach is scalable to building applications because it never starts with the entire building model; it always starts with a few elements explicitly touched by the user and continues with selective propagation of changes - minimizing the number of elements that must be updated.

### Is it Really a Parametric Building Modeler?

The essence of the architectural design of a building is in the relationships that can be embedded in the building model. The creation and manipulation of these relationships is quite literally the act of designing. Parametrics gives designers direct access to these relationships and are natural and intuitive ways of thinking about buildings using a computer, just as a spreadsheet is a tool for thinking about numbers or a word processor is a tool for thinking about words.

But not all BIM solutions are effective parametric building modelers as described above. The following are some examples of how a BIM solution built on a parametric building modeler performs in comparison to other technologies. Use these tests to determine if a solution is really a parametric building modeler.

**1) Does your software use you to coordinate and manage change?**

In a geometry-based product the user is normally expected to identify all of the geometry that is affected by the change, by selecting it with a "stretch box" or similar command. Geometry that's not visible or is turned off cannot be selected and will have to be found and corrected manually.

In a parametric building modeler like Revit, simply selecting and moving a wall in the first floor plan will cause all of the related elements to adjust automatically. The roof will move with the wall preserving any overhang relationship, the other exterior walls will extend to remain connected to the moved wall, and so on. This associativity is a defining feature of a true building information modeler.

**2) Are the terms "extracted" or "generated" used to describe the creation of drawings?**

If so, this is a clear indication that it's a geometric modeler. Some software includes libraries of commands or utilities that regenerate or update drawings and schedules based on changes to a building model. But this process is strictly one-way, relying on CAD operators to make sure all of the updates have been made. This operation is analogous to running another set of reports on a database after the data has been updated; the reports are just dead artifacts reflecting the state of the data when the report was run.

The test for a state-of-the-art parametric building modeler is the ability to coordinate changes and maintain consistency at all times. It's like working in a spreadsheet. Update the model in one place and all views, drawings, and schedules are instantly synchronized.

**3) If you slide a section key across a plan view, does the section update immediately?**

Conventional geometry-based products typically do not integrate graphic annotations into the building model. The full integration of drafting annotations into the building model itself is an important component to maintaining the connection between the graphic deliverables and the model. In a geometry-engine-based product, a dimension string will simply be text, or at best it may update if you change the underlying geometry. In a change-engine-based product, editing the dimension text will change the underlying geometry in a corresponding way.

Similarly, in a geometry-engine-based product, the section view and the section key line are usually separate and distinct. The section key line is simply a dumb annotation. In a parametric building modeler, a section key often serves to define the section cut itself. Move the section key line or flip the section key and the section view will immediately update.

**4) Does the BIM solution rely on "smart" or "intelligent" objects?**

Object-based modelers are common today. They include at the simplest level symbolic drafting aids, much like plumbing or furniture templates providing tracing guides for manual drafting. As the industry began to associate data such as a key number or name with these symbols they were dubbed "intelligent" or "smart." In some cases this data, such as a height dimension, could affect the geometry of the symbol making that data a "parameter" and the symbol "parametric." Other basic relationships such as "hosting" were

introduced between symbols, allowing a window to remain attached to a wall if the wall was moved.

However the missing piece is the network of relationships among and between *all* of the pieces of the building. This is the strength of a parametric building modeler: recording, presenting, and managing relationships no matter where they occur in the building.

An effective parametric building modeler manages object data at the component level, but more importantly allows information about relationships between all of the components, views, and annotations in the model. A door to a stairwell can be locked in place a specific distance from the riser of the stair to assure egress clearances; a door can be locked a specific distance from a wall to assure furnishing clearance or pull-side clearance for accessibility. The entire model contains information, not just the objects in it.

## Why Parametric Building Modeling Matters

Why is parametric building modeling so vital to BIM? BIM is an approach to building design that's characterized by the creation and use of coordinated, internally consistent computable information about a building project. Reliable building information is the essential feature of BIM and its digital design processes. BIM solutions that use parametric building modelers provide building information that is more coordinated, more reliable, of better quality, and more internally consistent than object-CAD software that has been re-purposed for BIM.

### Purpose-Built

Purpose-built BIM applications that use a parametric building modeler, like Revit, deliver this kind of information by design, through the natural operation of the software. When using a CAD or an object-CAD BIM solution, the graphical presentation of information (i.e., drawings or renderings) may look similar to the output of a purpose-built parametric building modeler, but is it coordinated, internally consistent, and reliable?

CAD-based technology is rarely used for BIM, due to the extremely high level of effort required to include and coordinate actionable building information such as schedule, cost, design scope, building performance, etc.

More sophisticated, object CAD systems store some (nongraphical) data about a building in a logical structure with the 3D building graphics. Users can extract this data to provide information about quantities and attributes, just as they extract the 2D drawings from the 3D graphics. But object CAD systems remain anchored to graphics. So additional tools (and effort) are required to keep the graphical and nongraphical data in sync - to assure the integrity and coordination of object CAD models and to deliver the benefits of BIM. One example of such a tool is Solibri Model Checker, which is designed to identify inconsistencies and errors in data produced from object CAD models before the data is used for other purposes. The larger the project, the greater the effort required to keep the data coordinated, and the greater the likelihood of inconsistencies.

A parametric building model combines a design model (geometry and data) with a behavioral model (change management). The entire building model and complete set of design documents is in an integrated database, where everything is parametric and everything is interconnected.

The analogy of a spreadsheet is often used to describe parametric building modeling. A change made anywhere in a spreadsheet is expected to update everywhere automatically. The same is true for a parametric building modeler - real-time self-coordination of the information in every view of the model. No one expects to have to manually update a spreadsheet. Similarly, no one has to manually revise a document or schedule from a parametric building modeler.

This bi-directional associativity and immediate, comprehensive change propagation results in the high-quality, consistent, reliable model output that is key to BIM, facilitating digital-based processes for design, analysis, and documentation.

## Essence of Design

Parametric building modeling captures the true essence of design - the designer's intent. In addition to simplifying the creation of buildings in software, the ease of parametric editing allows a more thorough examination of the design - which results in a better building design.

Revit-based parametric building modeling also supports design optimization, letting architects develop and study multiple design alternatives simultaneously within a single model. Design options can be toggled on and off in the model for visualization, quantification, and what-if analysis. The system keeps track of all the relationships within the design versions, and changes are effortlessly propagated throughout the model and all the design versions within the model.



**Figure 2**

Parametric building modeling allows firms to embed design and detailing decisions into the digital building model, like this one from Australian firm Architectus ([www.architectus.com.au](http://www.architectus.com.au)), so that the designer's vision is carried through into the construction documents.

## Design Analysis

In current practice, many digital building models don't contain sufficient information for building performance analysis and evaluation. As with traditional physical models and drawings, evaluating building performance based on the graphic representations of conventional CAD or object CAD solutions requires a great deal of human intervention and interpretation, which renders the analyses too costly and/or time-consuming.

In a parametric building model, much of the data needed for supporting design analysis is captured naturally as design on the project proceeds. The model contains the necessary level of detail and reliability to complete these analyses earlier in the design cycle, and makes possible routine analysis done directly by designers for their own baseline energy analysis - providing immediate feedback on design alternatives early on in the design process.

## Documentation

It is Autodesk's opinion that only a purpose-built data architecture built around a parametric building model can provide the immediate and fully coordinated set of accurate and reliable conventional documents. A BIM solution that can coordinate changes and maintain consistency at all times lets users focus on building design versus change management. This built-in change-management capability is critical to the disconnected building process - which is still heavily dependent on construction documentation - providing confidence in drawing deliverables.

## Reliable BIM Foundation

While the notion of a digital building model is not new, BIM is creating renewed interest in the use of digital building information to support greater efficiencies in business processes. But just because an authoring tool can produce a digital model doesn't mean it's suitable for BIM. A BIM solution using parametric building modeling provides you reliable digital building information feeding those business processes.

## About Revit

The Revit platform is Autodesk's purpose-built solution for building information modeling. Applications such as Revit Architecture, Revit® Structure, and Revit® MEP built on the Revit platform are complete, discipline-specific building design and documentation systems supporting all phases of design and construction documentation. From conceptual studies through the most detailed construction drawings and schedules, applications built on Revit help provide immediate competitive advantage, better coordination and quality, and can contribute to higher profitability for architects and the rest of the building team.

At the heart of the Revit platform is the Revit parametric change engine, which automatically coordinates changes made anywhere — in model views or drawing sheets, schedules, sections, plans... you name it.

For more information about building information modeling please visit us at <http://www.autodesk.com/bim>. For more information about Revit and the discipline-specific applications built on Revit please visit us at <http://www.autodesk.com/revit>.



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