

Conceptual Design and Analysis in Autodesk Revit Architecture 2011

In this white paper, CASE Design, a design technology consultancy based in New York City, describes how Autodesk® Revit® Architecture can be used to create massing designs; explore design alternatives based on qualitative and quantitative feedback; and help address various environmental, constructability, and aesthetic concerns that can arise during project realization.

In the early stages of a design, visualizing a concept in 3D enhances a designer's ability to communicate ideas. Analyzing these ideas yields the ability to predict and optimize the real-world performance of the built project. These attributes form a core value of the building information modeling (BIM) process, which Revit Architecture software is purpose-built to support.

In Revit Architecture 2011, users have access to a robust collection of easy-to-use modeling tools that facilitate design conceptualization, visualization, and communication. This release supports several new modeling operations, including adaptive, component-driven geometry, robust UV grid manipulation, and increased schedule functionality through reporting parameters. In addition, Revit users on Autodesk® Subscription can now access tools that enable them to better assess the impact of their early design decisions on energy consumption and carbon emissions without leaving the Revit environment.

In order to clearly illustrate a complete workflow using the conceptual design and analysis tools, and to address the new features introduced with this release, this white paper has been divided into four sections. The Project Requirements section outlines the criteria that will drive the building design. The Parametric Massing Design section describes the steps taken to explore massing design alternatives informed by qualitative and quantitative feedback. The Site and Environmental Analysis section addresses the impact of building mass and orientation on energy consumption and overshadowing. The Custom Panelization section uses the mass design options generated in the first section as the basis for informed panelization studies.

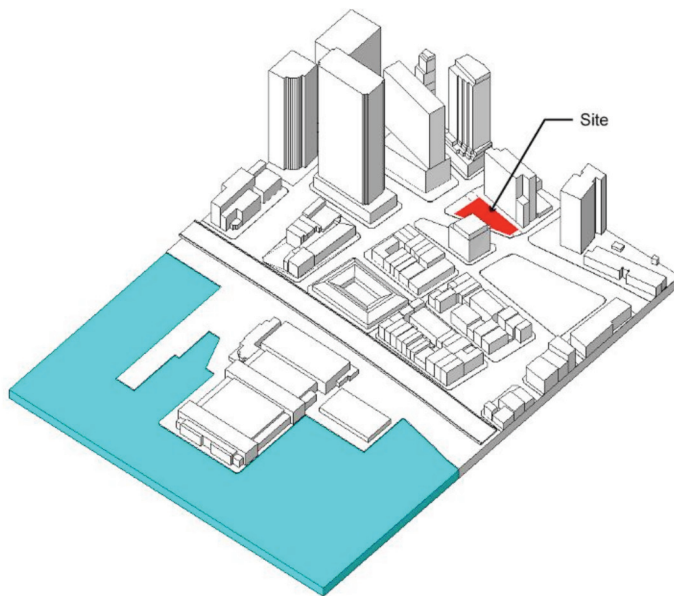
1. Project Requirements

While approach and attitude about design may differ from firm to firm, most designers would agree that iterative design can lead to more optimal solutions. However, several concerns arise, such as: How does a designer find the best solution for any given project? How can design criteria be used more effectively to evaluate possible design solutions? And finally, how can technology help make this exploration and discovery process more informative and efficient?

With regard to the specific project explored in this white paper, several key constraints affected the outcome of the design.

1.1 Site and Context Requirements

The site for the tower is located on the edge of a high-rise business district, adjacent to a low-rise residential district near a waterfront. The site is an undeveloped triangular parcel bordered by two major streets. An existing secondary street to the north of the site will be closed and incorporated into the buildable footprint of the parcel.



Project site

1.2 Programmatic and Planning Requirements

The tower will be a mixed-use building. The lower portion will be a hotel (approximately 7,000 square meters) with residential units above (approximately 19,000 square meters).

The unusual shape and context of the site present challenging planning requirements. The design must meet the stated programmatic requirements within a tight footprint of 930 square meters, while not exceeding 150 meters in height. Furthermore, the design should minimize the impact of overshadowing on the adjacent buildings and streets.

1.3 Environmental Requirements

Another challenge requires the building's life cycle energy costs and overall carbon emissions to be minimized.

2. Parametric Massing Design

The conceptual mass environment supports both surface and solid modeling workflows. The solid modeling workflow maintains the benefits of working with mass families, such as the use of the Add Edge tools. It also provides access to the new adaptive component family, which significantly enhances the ability to create iterative design models.

With these tools, surfaces can be created and manipulated, or they can be thickened to create solid masses. Both surfaces and solid faces can serve as the basis for custom panel families. This white paper focuses primarily on the parametric solid modeling workflow—the most appropriate technique for a volumetric design—and demonstrates how these masses can be incorporated into a Revit Architecture project.

2.1 Maximizing Buildable Volume

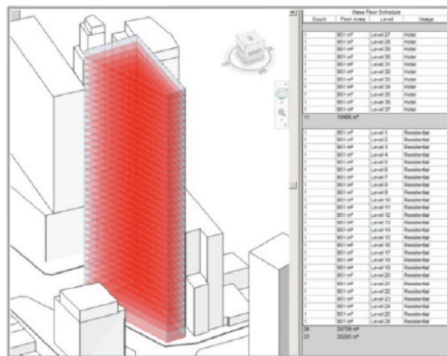
To visualize the extents of the maximum buildable volume, the full parcel is extruded to the maximum height (150 meters) using the Create Form button.

This conceptual mass family is placed into a Revit Architecture project containing the site and surrounding context. Levels are then used to create mass floors from the maximum buildable volume and a mass floor schedule is generated showing a total buildable area of 46,600 square meters.

Although these results might be ideal for the project developer, they leave much to be desired from both urban and aesthetic perspectives. In addition, city planning officials would likely have concerns about the impact of the tower on overshadowing. However, by utilizing the new conceptual mass tools in Revit Architecture, these design issues can be readily addressed.



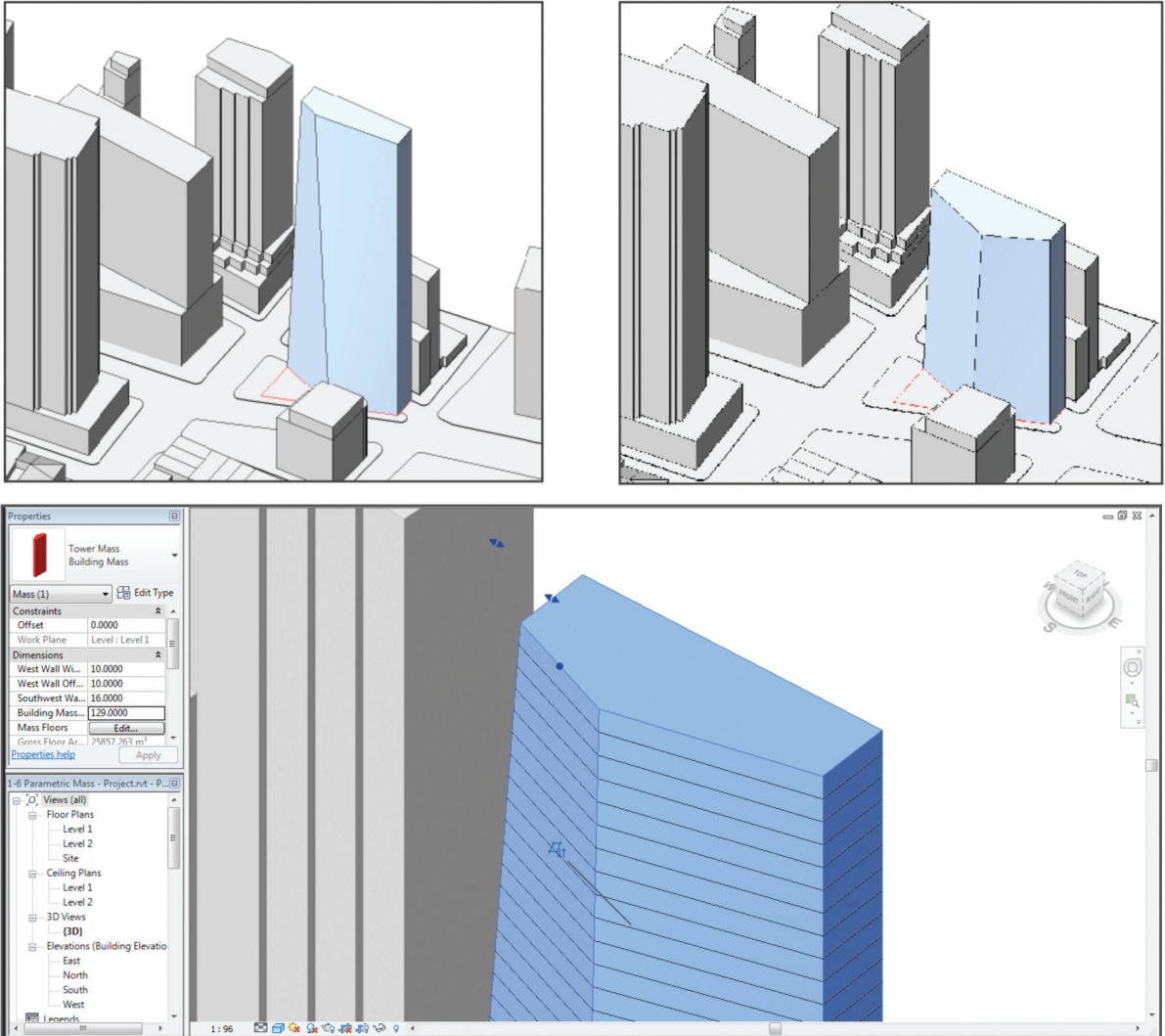
Conceptual mass in project



Mass floor schedule

2.2 Creating a Parametrically Controlled Mass

In order to maximize the tower model's flexibility, it is built as an in-place mass from a system of parametrically related reference planes and lines. Dimensional parameters, t-value parameters, and points hosted to intersects are all utilized to construct an adjustable framework. As the tower family's shared instance parameters are adjusted from within the project, the corresponding tower mass updates instantly.

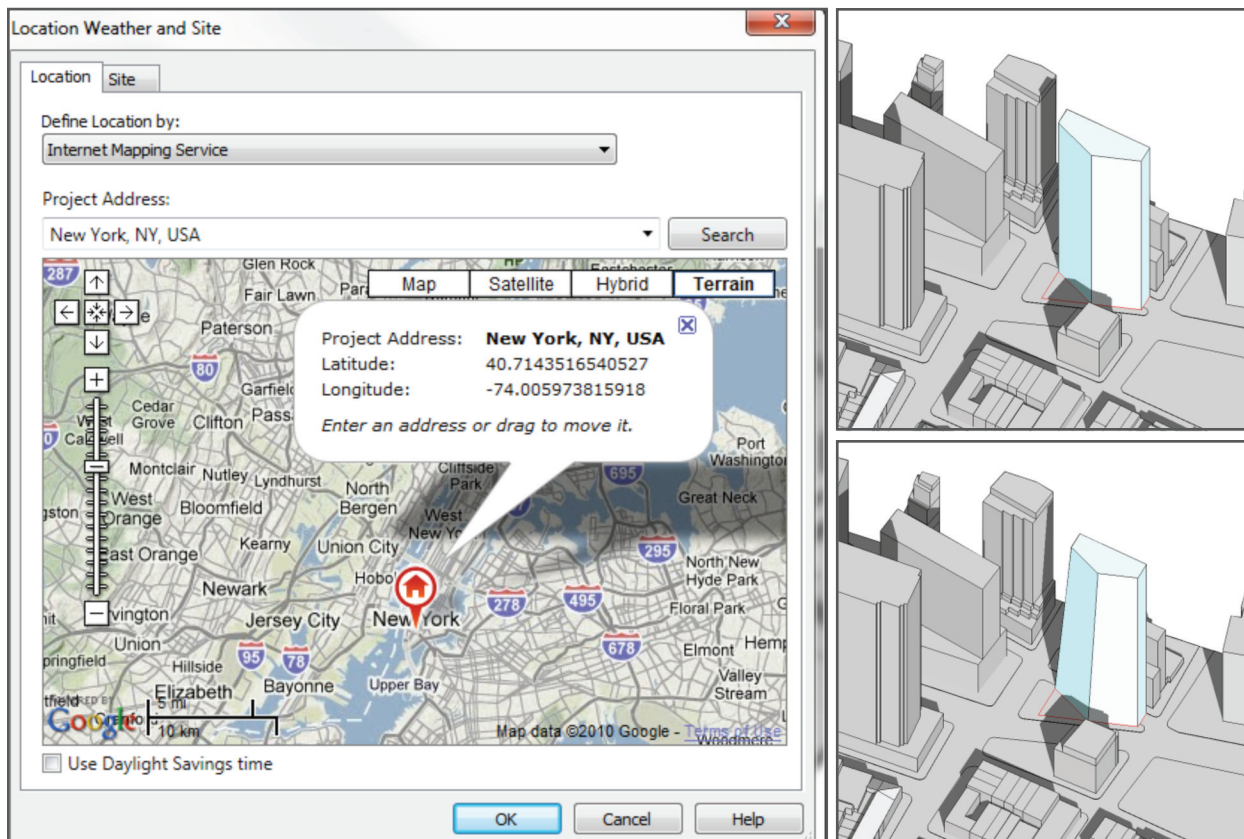


Modifying tower mass using shared parameters

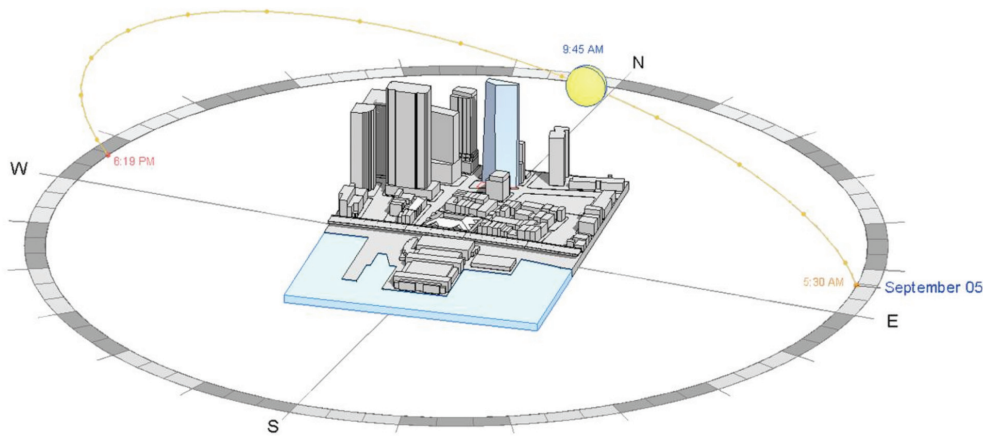
3. Analysis: Adapting to Physical Constraints

3.1 Minimizing the Impact of Shadows

Reducing the bulk of the tower and the impact of its shadows on neighboring buildings and streets is the primary concern at this stage of the design process. By enabling the interactive Sun Path and Shadow tools within Revit Architecture, the design team can more quickly identify troublesome areas. Team members can set the location of the project via a graphical map interface and use the resulting latitude and longitude be used for shadow calculations and downstream analysis, shown below. After the building envelope is imported into the project environment as a mass, sun path studies reveal that the proposed envelope casts large shadows onto existing buildings to the west. By modifying the mass directly, the western face of the proposed envelope is narrowed. In addition, the top edge of the western face is shifted in, further reducing overshadowing and creating a more sculptural mass. With these simple actions, the project team can reduce the effects of overshadowing, create a more iconic design, and evaluate whether the modifications meet program targets.



Project location interface and shadow analysis

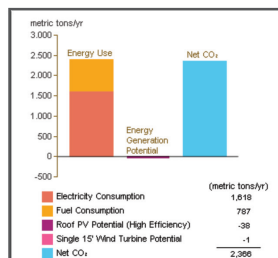
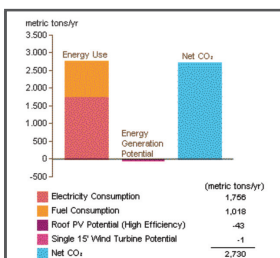
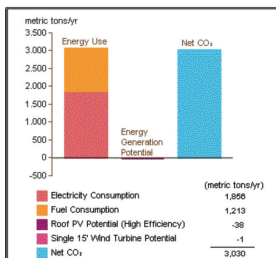
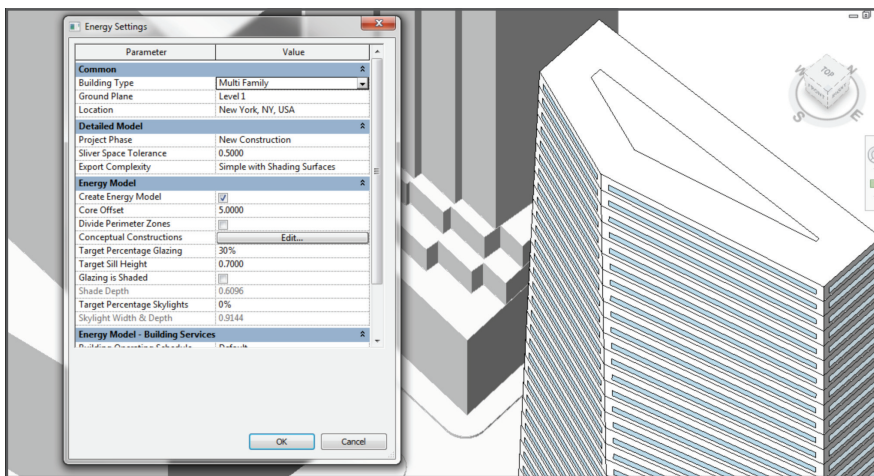


Interactive sun path

3.2 Minimizing Energy Consumption

Now that the tower mass has been refined based on bulk regulations and overshadowing, the team can begin to study design options that will reduce the project's overall energy consumption. Using the new Conceptual Energy Analysis tools, the team is able to quickly and easily generate an analytical model from the parametric mass. This model can then be uploaded to a cloud-based analysis engine to generate graphical building performance results. The Energy Settings dialog box allows the project team to specify the default building type, project weather location, basic thermal zones, conceptual material assemblies, percentage of glazing, solar shades, operating schedule, and HVAC system. These settings can then be overridden at the space or surface levels in order to refine the model.

The energy model is kept in sync with the massing model, so changes to the building form are automatically propagated to the energy model, helping to save the team a great deal of time and effort. By running an analysis on the initial form and then making changes to the overall mass, increasing the insulation in the exterior walls and roof, increasing the SHGC of the windows and reducing the percentage of glazing from 40 to 30 percent, the team can reduce the overall carbon emissions and life cycle energy costs by 12 percent. By adding 0.5-meter-deep solar shades on the south-facing windows, the team can shave another 2 percent off of CO₂ and lifecycle energy costs. On a project of this scale, these potential energy savings over the project lifecycle could be in the millions of dollars.



Energy settings, analysis model, and annual carbon emissions reports.

4. Custom Panelization

4.1 Creating the Custom Panel

The new adaptive component family can be utilized in conjunction with reporting parameters through the curtain panel pattern-based system, which automates the placement of context-aware panel families onto patterned mass faces. The result is a simplification of a once complex technique, now making it more accessible to all building designers. The team identified two key requirements for the design of custom panels for the tower project:

Cost and Constructability

The designer should use precise material takeoffs and surface area calculations to assist in determining the feasibility of different panelization designs. Additionally, with respect to the construction process, a decision should be made as to whether off-site or on-site fabrication is the more cost-effective and appropriate solution.

Aesthetics

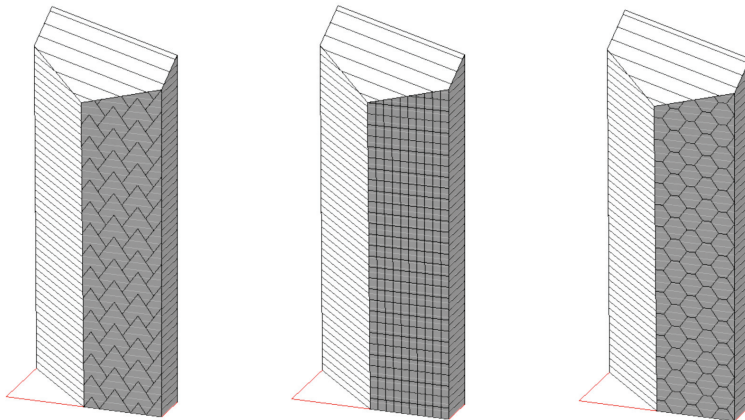
The panel pattern should be iteratively studied and aesthetically related to the geometry of the mass, ultimately contributing to the iconic qualities of the tower design.

4.2 Defining the Pattern

In order to more quickly test different paneling options, the Divide Surface tool is used on the faces of the conceptual mass. Initially, the isocurves (UV) of the surfaces are displayed based on either the number or spacing specified in the Options bar.

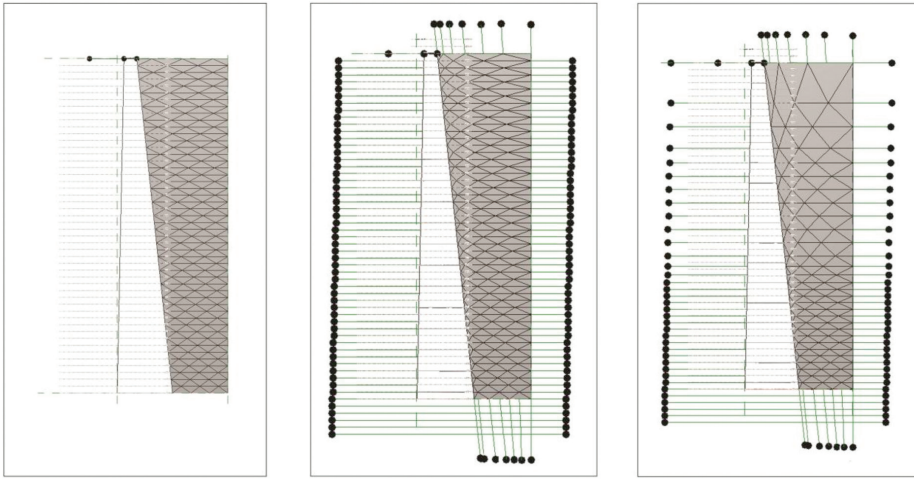
These curves and their intersections form the basis of various predefined patterning options selected from the Change Element Type drop-down list.

Visibility of these patterns is toggled using the Pattern Visibility button. Spacing, rotation, and justification of the pattern are easily controlled by directly interacting with the model and receiving visual feedback.



Standard Revit patterns applied

Revit Architecture now includes several pattern-defining tools within the divide surface interface that give users extensive command over curtain pattern spacing and face matching. The Intersects Lists tool now allows the user to define UV grid placement based on floor level and reference plane, while the Intersects tool allows sketched reference lines to drive placement. U spacing can be maintained across building faces by specifying the same floors through Intersects Lists, while V spacing can be blended across nonuniform corner conditions by specifying common corner profiles in the Intersects tool so that adjacent building faces share curtain panel seams.



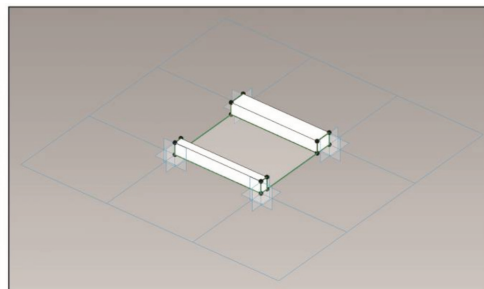
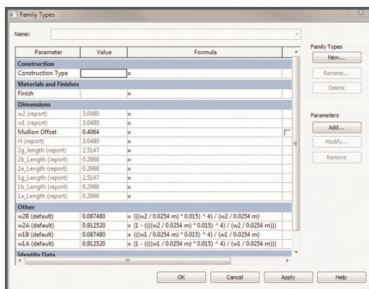
Custom patterns utilizing reference lines

4.3 Customizing the Square Panel

Within the custom panel family environment, a square pattern is used as the basis for a new panel family.

The depth of the frame is controlled using an interactive dimensional parameter, while the width is modulated as a line-hosted point t-value. The t-value parameter is controlled by a reporting instance parameter, which measures the width of each panel and runs it through a simple exponential equation. The result is a mullion width that is dependent on the panel width. This allows the project team to vary the density of the panel based on constructability and aesthetic considerations.

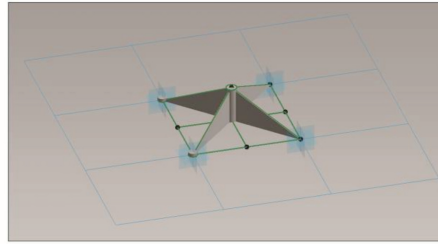
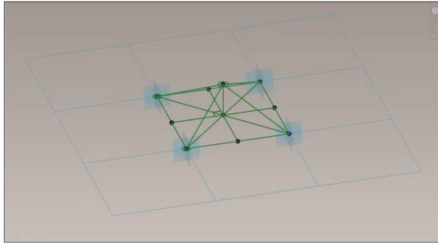
Finally, the faces and the frames are dimensioned and converted to reporting parameters which allows areas to be calculated from the project schedule once panels are applied.



Custom square panel

4.4 Customizing the Rhomboid Panel

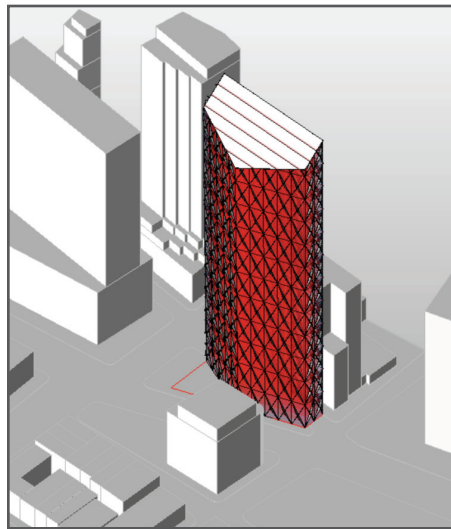
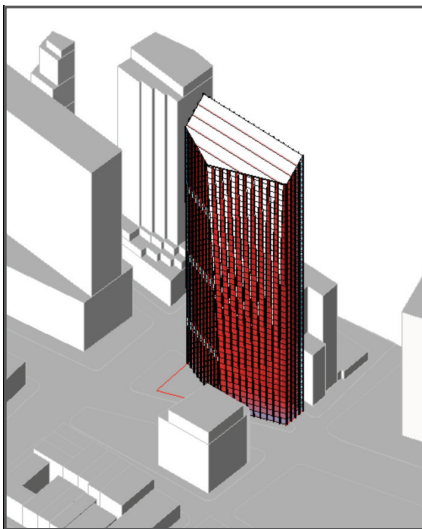
Another custom panel family is created to host a glazing spider element using the rhomboid pattern. The depth of the element's projection can be controlled using an interactive dimensional parameter. Like the square panel, reporting parameters are applied to dimensions, making it possible to schedule surface areas after the panels have been populated.



Custom rhomboid panel

4.5 Populating the Panels onto the Building Form

With two panel families created and loaded into the conceptual mass model, new panel families are chosen from the Curtain Panel Properties drop-down list, making it possible to apply panels to each face of the mass. Individual modifications are then made to the panels based on aesthetic requirements. This is done by selecting the appropriate panels and switching between the different family versions that were created.



Custom square and rhomboid panels applied to tower mass

4.6 Using Quantitative Data to Inform Final Design

Now that the panelization approach for each mass has been determined, scheduling tools are used within the Revit Architecture project to quickly calculate the number of panels and the surface area of each material used. Although masses are hosted by both adaptive- and pattern-based component systems, the masses remain schedulable as curtain systems due to their nesting hierarchy. These capabilities are extended by the ability of reporting parameters to pass context-based family information into project schedules. The unique dimensions of each panel are linked to a panel schedule with reporting parameters and then used to calculate the surface area of glazing and cladding.

Since the underlying masses are controlled parametrically, the project team can continue to update and refine the design based on this information, incorporating real-time feedback and modifications, until a solution that meets the project requirements is reached.

Family	ta_Length	tb_Length	ta_Length	tb_Length	Panel Schedule #	tg_Length	tg_length	srfa_Glazing	srfa_Mullion	srfa_Tot	% Glazing
Mullion_E	0.20	0.09	0.23	0.10	3.00	2.01	2.04	3 m²	0 m²	3 m²	87.42
Mullion_E	0.20	0.09	0.23	0.10	3.00	2.01	2.04	3 m²	0 m²	3 m²	87.42
Mullion_E	0.23	0.10	0.26	0.11	3.00	2.04	2.06	3 m²	1 m²	4 m²	86.19
Mullion_E	0.23	0.10	0.26	0.11	3.00	2.04	2.06	3 m²	1 m²	4 m²	86.19
Mullion_E	0.26	0.11	0.30	0.12	3.00	2.06	2.07	3 m²	1 m²	4 m²	84.80
Mullion_E	0.26	0.11	0.30	0.12	3.00	2.06	2.07	3 m²	1 m²	4 m²	84.80
Mullion_E	0.30	0.12	0.34	0.13	3.00	2.07	2.08	3 m²	1 m²	4 m²	83.26
Mullion_E	0.30	0.12	0.34	0.13	3.00	2.07	2.08	3 m²	1 m²	4 m²	83.26
Mullion_E	0.34	0.13	0.39	0.15	3.00	2.08	2.09	3 m²	1 m²	4 m²	81.54
Mullion_E	0.34	0.13	0.39	0.15	3.00	2.08	2.09	3 m²	1 m²	4 m²	81.54
Mullion_E	0.39	0.15	0.44	0.16	3.00	2.09	2.09	3 m²	1 m²	4 m²	79.62
Mullion_E	0.39	0.15	0.44	0.16	3.00	2.09	2.09	3 m²	1 m²	4 m²	79.62
Mullion_E	0.44	0.16	0.51	0.18	3.00	2.09	2.08	3 m²	1 m²	4 m²	77.49
Mullion_E	0.44	0.16	0.51	0.18	3.00	2.09	2.08	3 m²	1 m²	4 m²	77.49
Mullion_E	0.51	0.18	0.58	0.20	3.00	2.08	2.06	3 m²	1 m²	4 m²	75.11
Mullion_E	0.51	0.18	0.58	0.20	3.00	2.08	2.06	3 m²	1 m²	4 m²	75.11
Mullion_E	0.58	0.20	0.67	0.23	3.00	2.06	2.03	3 m²	1 m²	4 m²	72.46
Mullion_E	0.58	0.20	0.67	0.23	3.00	2.06	2.03	3 m²	1 m²	4 m²	72.46
Mullion_E	0.67	0.23	0.76	0.25	3.00	2.03	1.99	3 m²	1 m²	4 m²	69.52
Mullion_E	0.67	0.23	0.76	0.25	3.00	2.03	1.99	3 m²	1 m²	4 m²	69.52
Mullion_E	0.76	0.25	0.87	0.28	3.00	1.99	1.93	3 m²	2 m²	5 m²	66.25
Mullion_E	0.76	0.25	0.87	0.28	3.00	1.99	1.93	3 m²	2 m²	5 m²	66.25
Mullion_E	0.87	0.28	1.00	0.31	3.00	1.93	1.86	3 m²	2 m²	5 m²	62.61
Mullion_E	0.87	0.28	1.00	0.31	3.00	1.93	1.86	3 m²	2 m²	5 m²	62.61
Mullion_E 441	0.87	0.28	1.00	0.31	3.00	1.93	1.86	3 m²	2 m²	5 m²	62.61
Grand total: 1613											

5. Conclusion

This white paper and speculative project demonstrate some of the potential uses of the new conceptual design and analysis tools available in Autodesk Revit Architecture 2011 software. The enhanced conceptual design environment helps give designers a notable advantage through the pairing of robust parametric modeling tools for early concept development with simple and direct energy analysis tools, all within an already comprehensive and mature BIM platform. The result is a natural extension of the Revit Architecture design environment into a highly capable conceptual design solution for sophisticated form exploration, early-stage building performance analysis and visualization, and custom panelization and reporting.



6. About the Authors

CASE is a virtual design and construction (VDC) and integrated-practice consultancy based in New York City. We provide strategic advising to building design professionals, contractors, and owners seeking to supplant traditional project delivery methods through technology-driven process innovation. We help clients identify, implement, and manage the technologies and business practices that enable more effective coordination, communication, and collaboration throughout all phases of the building lifecycle. For more information, visit us online at www.case-inc.com.

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