

Demystifying Generative Design

For Architecture, Engineering,
and Construction



What is generative design?

Imagine you are planning the interior for an office building. In one scenario, your first step is to define the design parameters by describing the amount of light you want for desks depending on the season, the desired views for conference rooms, and the maximum amount you want to spend for construction. After you define the criteria, your design tools generate all the best possible outcomes with a single analysis, and evaluate the alternatives. This all takes place in a fraction of the time that it normally takes you to manually arrive at one or two best guess approximations.

In the other scenario, you sit down and manually calculate how your design parameters impact other aspects of the office building like energy loads and construction costs. You tediously go through the hundreds of location variables—kitchens, bathrooms, desks, or communal space placements—produced by your choices as the design develops. This entire process takes days or weeks as you review the options.

How might it change the way you design if, like in the first scenario, your software could help discover the implications of the goals you define instead?

Now think about a typical construction project and shifting your approach to the actual procedure of building—and not just what you're building, but how it is built. Cost overruns and waste are always the enemies of construction. What if you could mitigate these potential risk factors with better recommendations on materials or by scheduling and sequencing job site work? What is the right strategy for placing precast concrete panels? Or the optimum placement of a crane? A software algorithm can test numerous scenarios for potential solutions to find the best one.

These are the objectives of generative design; a technique that uses computation to augment the designer's ability to define, explore, and choose alternatives through automation. Generative design is more than a methodology; it embodies many applications and techniques. It will continue to grow more potent and useful with technology advancements such as artificial intelligence and machine learning. **But, at its heart, generative design is about providing practitioners with the ability to quickly explore, optimize, and make informed decisions to complex design problems.**

Generative design

/ gen·er·a·tive de·sign/

noun

A goal-driven approach to design that uses automation to give designers and engineers better insight so they can make faster, more informed design decisions. Your specific design parameters are defined to generate many—even thousands—of potential solutions. You tell the software the results you want. With your guidance it arrives at the optimal design along with the data to prove which design performs best.

Think of generative design software as an assistant that helps with creating, testing, and evaluating options.

And it may well provide scenarios you might have never imagined, allowing you to do even more with less—whether that’s less time or resources. But, ultimately, it’s up to you to make the decision of what’s right for your project and the priorities.

While all of this may sound wildly futuristic, generative design is already changing how decisions are made during all phases of the design and construction process. Here, we’ll explore what generative design means to the AEC industry.

“I call generative design my virtual design associate. It takes care of all the process work and option analysis...It creates a better series of options that you can then pick and choose based on your case and implement it.”

M. Mehrdad Tavakkolian
VDC/BIM Solution Architect

The power of computation

Generative design is a definitive shift in how to conceptualize, design, and build. At its core, generative design is a strategy that augments human capabilities by using algorithms to automate your design logic. You still define the design parameters, but instead of modeling one thing at a time, generative design software helps you—the designer—create many solutions simultaneously and sometimes even find “happy accidents” or unanticipated and unique solutions that would be difficult to discover with traditional methods.

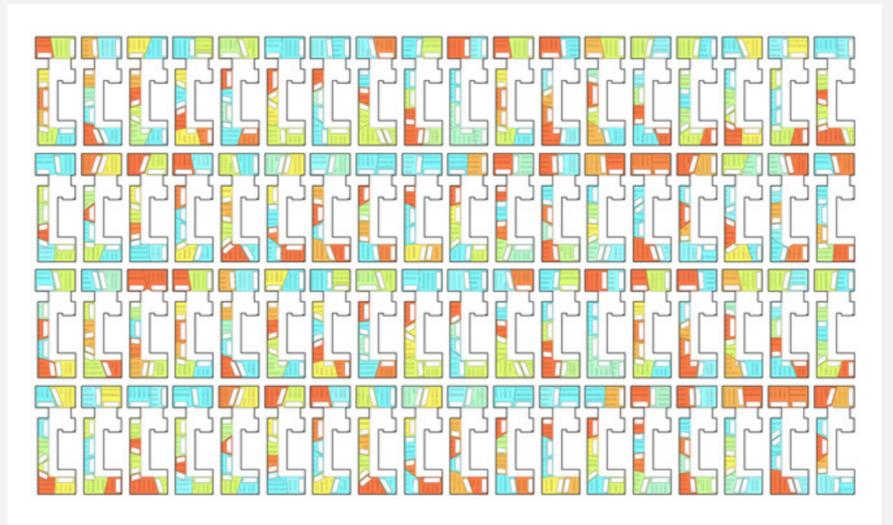
This type of automation isn’t new in design software—it’s just growing up. For example, think about the early days of AutoCAD®’s AutoLISP, where simple scripts automated routine tasks. Or the powerful capabilities of Dynamo combined with Autodesk Revit®. The change now is that scripting and algorithms control much larger chunks of functionality and can manage much bigger swaths of data and analysis.

Autodesk evaluates 10,000 design options using its own generative design solution

For the design and planning of a new Autodesk office and research space in the MaRS Innovation District of Toronto, we pushed the limits of generative design for architecture. We started with high-level goals and constraints, collecting data from employees and managers about work styles and location preferences. We then developed six primary and measurable goals: work style preference, adjacency preference, low distraction, interconnectivity, daylight, and views of the outside. We created a geometric system with multiple configurations of work neighborhoods, amenities, circulation, and private offices. We then used the power of cloud-based computation to generate, evaluate, and evolve 10,000 different design options to arrive at the final, optimized design for our new office.

This approach offers many benefits for designing office space including:

- Managing complexity
- Optimizing for specific criteria
- Augmenting human creativity and intuition
- Incorporating a large amount of input from past projects and current requests



- Navigating trade-offs based on real data
- Structuring discussion among stakeholders about design features and project objectives
- Offering transparency about project assumptions and offering a “live model” for post-occupancy monitoring and restacking
- Discovering unanticipated design solutions

The history behind scripts, algorithms, and generative design

“Architects have been using scripting for decades to take the geometry created by a computer and manipulate it in new ways, and a new generation of building design and construction was born. Computers overruled the tyranny of the right angle, and shapes and curves became possible not to just draw but to build.

“Those original scripts drove the programs available at the time, and forms like Zaha Hadid’s Heydar Aliyev Center were born. But today scripts create algorithms that can control a much wider array of the digital tools deployed for building, yielding a new strategy with generative design and construction—a name that reflects not just the power that generative tools give architects and builders, but the important connection between the design and construction process that generative tools make possible.”

—Phil Bernstein, Associate Dean and a Senior Lecturer at the Yale School of Architecture; Autodesk Fellow



A look at productivity, time and cost savings, and waste

Whether you're an engineer, contractor, or an architect, the same age-old battle continues to rage: more work in less time and at less cost. According to Technavio, the global architectural engineering and construction market is set to grow at a CAGR of 11.8% during the period 2017-2021. Increasing labor shortages add more complications. Recently, the USG Corporation and the U.S. Chamber of Commerce reported that more than half (57% of contractors) want to employ more workers in the next six months but are challenged by availability and cost. Budgets, schedules, and build quality are all challenged as a result.

Keeping up with this demand and delivering cost-effective, sustainable results requires new ways of working and adoption of technologies. There's simply more work than can be done with current methods and the size of workforce. That means automation isn't just an option—it's a requirement to compete and deliver on the number of projects needed around the world.

One of the allures of generative design is the opportunity to reduce those tedious tasks eating up your time so you can focus on more complex problems. This type of automation frees you up to focus on more projects and strategic decision-making.

“Taking advantage of generative design means acknowledging that computers can do a better job with certain kinds of low-level analytical tasks, like checking to make sure all the doors are swinging in the right direction, the stairs are wide enough, or the type of glass in the window wall is actually performing in the context of the overall energy goals,” says Phil Bernstein, Associate Dean and a Senior Lecturer at the Yale School of Architecture and Autodesk Fellow. “Doing this frees a designer to focus on more important things, such as the overall solution for a building, the experience of an entrance lobby, or the appropriate massing for a neighborhood. The best answers to these design problems can't be ‘generated’ by a computer—only the human mind.”

“A lot of people think of computers, they think of automation, and they instantly sort of say, ‘Oh, does that mean you can do everything in a fraction of the time?’ But for us, we don't think it's so much [about] reducing the timelines, where something that takes you a hundred hours suddenly reduces to 50. It's the fact [that] what you can do within those hundred hours is so much more.”

—Krieh Bachmann, Manager of Design Technology, DIALOG

While computation can reduce the drudgery of repetitive tasks, generative design methods also help design and construction teams reach the ultimate goal of reducing waste and cost.

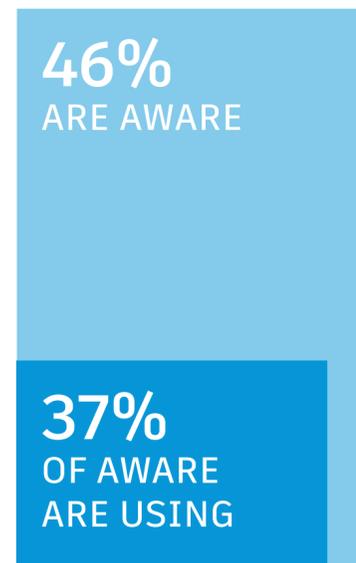
Setting up an algorithm to minimize the use of materials or consumption of energy naturally reduces costs and makes construction more efficient. That's what Van Wijnen, a family construction business based in the Netherlands, did.

With a focus on building sustainable and affordable housing, the company turned to generative design to explore 15,000 different design options for a new land development project. Using generative methods, Van Wijnen could narrow to three of the most interesting choices to shape into the perfect urban neighborhood. They then selected the optimal choice that maximized solar energy collection and met net-zero energy goals, while simultaneously optimizing yard size and views for the residents. Best of all, Van Wijnen designers could input cost and profit into their preferences for the optimum solution.

“Generative design gives us the opportunity to let the computer make as many options as you want,” says Hilbrand Katsma, COO, Van Wijnen. “[It] lets us create both beautiful neighborhoods and homes that our customers love living in, but also makes sure we can meet our goals of net-zero energy. It's better for our customer, better for the community, and better for the environment.”

Generative design use set to increase

According to research, nearly half of design firms (46%) are aware of generative design tools and over a third (37%) currently use them.



SOURCE: *Leading the Future of Building: Connecting Design Insight*

Generative design is seen to enable the following:

- Generate and explore more design alternatives that produce better, more functional final solutions
- Improve quality, budget control documentation, and constructability
- Automate routine tasks



Generative design empowers the AEC industry with new and potent capabilities.

While an algorithm is still just an algorithm, only a human is going to decide what problem to solve, what goals must be achieved, and what factors are most important to solve a problem.

Computers can help organize and prioritize those decisions but can't actually make them—only people can decide what's important.

Generative design gives architects, engineers, and builders new freedom to design and make a better world.

[Learn more](#) about how generative design is being used by your peers to change the way they approach design.



